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DISCUSSION ON PAPER CLXXX.

THE CONSTRUCTION AND MAINTENANCE OF ROADS.*

AT ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879, AND AT MEETING OF THE SOCIETY, OCTOBER 1ST, 1879.

By ARTHUR SPIELMAN and CHARLES B. BRUSH, GEORGE D. ANSLEY, A. B. HILL, CHARLES DOUGLAS FOX, E. LAVOINNE, E. B. VAN WINKLE, B. F. MORSE, E. S. CHESBROUGH, E. R. ANDREWS, C. SHALER SMITH, M. MERRIWETHER, J. E. HILGARD, D. E. MCCOMB, F. RINECKER. J. J. R. CROES, JOHN BOGART, C. C. MARTIN AND EDWARD P. NORTH.

A. SPIELMAN AND CHARLES B. BRUSH (SPIELMAN & BRUSH).—Some of the views expressed in Mr. North's paper on "the construction and maintenance of roads," being at variance with the results of the experience of our firm, in the building of 36 000 square yards of Telford roads in 1875 and 1876, and about 25 000 square yards in 1878 and 1879, part of this latter amount being now in the course of construction, we herewith submit the principal facts in relation to these roads, and our conclusions therefrom.

The roads are 80 feet wide between house lines, and are located in the

* Paper CLXXX. By Edward P. North. Vol. VIII, page 95. May, 1879.

northern part of Hudson County, New Jersey; they are built exclusively of trap rock, obtained from and along the line of the road, the stone for the upper courses having been broken by a stone crusher erected on the road by the contractor, the average haul from the crusher not exceeding 2 000 feet. No binding except the screenings and detritus of the stone was allowed in the work, and in each case, the foundation is of rubble, 8 inches deep, and the superstructure of broken stone, 4 inches thick, when compacted.

The roads built under our direction in 1875—1876, may be divided into two classes :

1. Roads by the side of horse railroad tracks.
2. Roads free from horse railroad tracks.

In the first case the width of the roadway from curb to curb is 55 feet, which includes 18 feet of trap block pavement for the tracks, and 5 feet for the gutter.

In the second case the width between the curbs is 40 feet, including 5 feet of block pavement for the gutter.

In both cases the 8-inch foundation was first carefully laid, and great care taken to allow for perfect sub-drainage. Cess-pools, filled in with broken stone, were built at intervals of about 200 feet on both sides of the road, which collect all the water that accumulates in the foundation of the pavement, and these cess-pools are drained by 6-inch stone ware pipes into adjoining receiving basins.

A particular illustration of the importance of this sub-drainage came under our notice. In December, 1875, just after considerable of the foundation had been laid, legal difficulties arose, the work was suddenly stopped, and remained in this unfinished condition until the spring of 1876, receiving in the meantime the wash from the adjoining hill-sides. When the work was recommenced the interstices between the foundation stones of the pavement in many places were filled in with earth. After unsuccessfully attempting to remove this earth, the foundation at these points, as far as they could be ascertained, was taken up and relaid; but as soon as the superstructure of the road was completed we found that, in certain spots, it was always wet, and the surface of the road was continually broken. These spots invariably indicated the points where the foundation was clogged, and the difficulty was only effectually remedied by relaying the foundation, or by building blind drains which carry off the accumulating water.

On the top of the foundation thus prepared, 2-inch stone was then put on, sprinkled, and rolled with a horse roller of 150 pounds per inch run. The one-inch stone and screenings were then spread, sprinkled, and rolled with a steam roller of about 400 pounds per inch run.

After the rolling was partially completed the passing traffic was allowed upon it, and any large stones that came to the surface, as well as all small stones that failed to bind, were raked off and sent back to the crusher to be re-broken for screenings. No water-worn or other rounded stones were allowed in the work. Advantage was taken of every rainfall to roll the surface of the road, because we found that it could be compacted much more thoroughly in wet than in dry weather. Where the pavement was laid on a soft substratum it required nearly double the amount of rolling sufficient for a solid foundation.

The grades of these roads vary from 6½ feet to 8 inches per 100 feet, and the crowns vary from 12 inches to 8 inches.

The roads have now been open for traffic about three years; those along the railroad tracks are used by about 600 wagons per day, the others by about 400 wagons per day. Fully one-half of the traffic on both roads consists of heavy beer wagons from the adjoining breweries, stone trucks and ice carts, ranging in weight from 3 to 6 tons; the balance of the traffic, of ordinary farm wagons, carriages, etc.

No especial care has been taken of the roads, except to see that the gutters and culverts are kept clean. No ruts have ever appeared, and the surface is now smooth and in good condition. In hot weather the roads are somewhat dusty, and in long dry spells they will loosen and break up in spots, where disturbed by the corked shoes of horses drawing very heavy loads, but after the first rain the surface immediately rebinds and again becomes perfectly smooth.

Wind and water are, perhaps, the two greatest enemies of Macadam roads; the wind, by blowing off the slight dust which naturally accumulates on the surface, removes from the road the cushion, which is not only a relief to the traveller, but which also preserves the metal of the road from a vast amount of wear and tear; the water, by flooding the road, has sometimes the same effect as the wind, and if by any means the surface of the road is exposed to a running stream the stones are sure to loosen.

The only effectual remedy we found was to raise the crown of the road sufficiently to shed the water quickly into the gutters, and to keep

the road sprinkled, so that when the winds and floods came the surface would be smooth and compact and not liable to their disintegrating influences.

On the roads by the side of the horse railroad tracks the wear has been about an inch and a half during these three years, while on the roads free from these tracks the wear has been about one inch on the crown and perhaps a half inch on the sides.

The cash cost of the Telford pavement laid under our direction in 1875–76 was ninety cents per square yard.

The stone was broken by a ten-inch "Blake" stone crusher at the rate of about twenty cubic yards in ten hours. The size of the stones as they came from the crusher was: 50 per cent., 2 inches size; 25 per cent., 1½ to 1 inch size; 25 per cent. screenings and pea dust.

The cost of the crusher, engine, boiler, &c., set up complete, was about $2 500.

The cost of working per day, independent of the original cost of the machinery and interest thereon, and also independent of any royalty on the stone, was found by the contractor to be as follows:

Repairs, lubricants, wear and tear on crusher and engine, about..	$6 00
1 engineer, $2.50; 1 feeder, $1.50; 1 screener, $1.50; 5 laborers quarrying and breaking up stones at $1.00.....	10 50
1 team hauling stone.....	5 00
Coal, half ton.....	2 50
Cost of preparing and crushing 20 cubic yards of stone.....	$24 00

Cost of 1 cubic yard, $1.20.

The roads built under our direction in 1878, and now building, are the same in every particular as those built in 1875–76, except that they occupy only 20 feet in width of the crown of the road; the steam roller was not used, and as it is very difficult to obtain an abundant supply of water in the locality, we have to rely on the rainfall for sprinkling, and do all our rolling in wet weather. A horse roller is used of 150 pounds per inch run.

Some 3 000 square yards of these roads were completed one year ago, and have been, since that time, subjected to a daily traffic of about 150 wagons, principally carts, loaded with stone and dirt. The surface of

the pavement is now as nearly perfect as it is possible to imagine that of a Macadamized road to be.

The cash cost of these roads is eighty cents per square yard.

CONCLUSIONS.

A Telford road may be practically divided into two parts.

1. The foundation, which should be uniformly secure, and which should be at the same time a perfect blind drain.

2. The superstructure, which should be a durable, water-tight roof.

If these conditions are complied with—if proper materials are used in the construction of the road, and reasonable attention is given to its maintenance, the result will be as has been claimed, a durable road, unsurpassed for comfort of travel, and one to be preferred to all others for sanitary reasons.

If these conditions are not attended to the road will last but a short time.

The foundation is of the first importance. It should be eight inches in depth. More than this is a waste of material, and a less depth is not sufficiently secure for want of proper bond. It must be laid as close as possible by hand, then the interstices at the top wedged and sledged, until the small stones that compose the superstructure can not work down, and fill the interstices at the bottom of the foundation.

Too much emphasis cannot be given to this part of the work. It is not only essential to perfect sub-drainage; it is equally important in the great saving of the cost of building the road. A loose foundation, which allows the small stones to settle down among the large ones, will require nearly as many again of the small stones before a proper surface can be obtained, hence the cost of the superstructure will be nearly doubled. Of course, if the small stones work down among the large stones, the latter will work up to the surface, and ultimately ruin the road.

An excellent test of a foundation, when the substratum is firm, is to drive a loaded truck—weighing about three tons—over the pavement before any of the upper courses are placed thereon; if the foundation has been properly laid no ruts or other displacement will occur.

As to the size of the foundation stones, we prefer them large rather than small. Nothing is so dangerous as thin slabs. A large stone now and then, say ten inches wide, well bedded, seems to act as an anchor

for the rest, and we have yet to find an instance where the small stones have broken loose from such a foundation stone.

In regard to the superstructure, we are convinced that if the material is crushed trap, any increase over four inches in depth is a waste of material. We found this to be the most expensive portion of the road, the cost of the eight inch foundation being to the cost of the four inch superstructure as one is to two. Four inches will answer all requirements as well as any greater depth, because after the metal has worn down two inches, the road, owing to unequal wear, will need to have a new coating in any event, and the amount saved in the first cost and the interest thereon, by making the superstructure only four inches deep, will keep the road in repair for many years.

In regard to steam rolling, it is often questionable whether it is essential, or even desirable, in the building of Macadamized roads, especially when the road is built of New Jersey trap rock.

The principal action of the steam roller is to crush the stone into the crevices, and the result is, that a crust is quickly formed. On the other hand, the horse roller rattles around and shakes the small stones about, until they are firmly bedded upon the rough but firm foundation and upon each other. No crust is formed, but, on the contrary, a compact homogeneous mass, which result is much more to be desired. Again, the road bed upon which the pavement is laid, often varies very greatly; frequently a rocky bottom adjoins a soft stratum, on one side of the road may be an excavation and the other side a fill. In such a case, a heavy roller is much more likely to disturb the uniformity of the foundation than a lighter one, no matter how great care may have been taken to provide for the emergency.

If it be necessary to finish the surface of the pavement within a week or two, a steam roller must certainly be used, but we believe that rapidly made roads are much less durable than those whose construction extends over a longer period of time.

It required at least three months to finally form the surface of the roads built by us in 1875–76, while on the roads now building, some of the sections have required as much as six months. In the meantime, the surface is kept free from loose and rolling stones, so that there is no brutal pulling through the road metal.

After a road has been slowly compacted in this way, we believe the surface will be found much more durable than that of any rapidly made steam rolled road.

As to "binding," our experience has been that during the construction of the road the less foreign material used the better, unless, perhaps, along the edges of pavement which has only an earth support. In such a case, it is necessary to bind the edges as quickly as possible, in order to prevent the sides of the road from spreading while the surface is forming. After that is accomplished, very little wear comes on the extreme edges of the road.

As an aid in the rapid formation of a fine surface, a little yellow clay placed just below the upper course is almost invaluable, but when the crust is broken the danger is that the surface will soon disintegrate, while if instead of the clay, stone dust is placed between the courses of broken stone, and a top dressing one inch deep of screenings, such as are presented herewith, is spread over the surface and is thoroughly worked into the broken stones, the surface is equally fine and much more durable; if a spot does loosen here and there, it does not spread and a little moisture quickly rebinds the loosened stones.

Finally, as to the stones for the superstructure, we greatly prefer machine-crushed to hand-broken stones.

1. Because they are much more uniform in size, each having actually passed through a revolving screen.

2. Because the edges of the stones are much sharper and bind better.

3. Because from the machine alone can we obtain the screenings and detritus which we consider so essential for compacting the road and for satisfactory top dressing.

George D. Ansley.—My experience is decidedly in favor of steam rolled Macadam or Telford roads over those formed by horse roller; in fact, I have altogether given up the use of the latter, and employ a 15-ton Aveling & Porter, the result being far greater economy in the end as to outlay, and a decidedly smoother and more permanent surface is obtained.

As to compacting with traffic, I am altogether opposed to it, as being inhuman towards horses and extravagant in the waste of material. I speak of the case when any considerable extent of roadway is to be covered; but in small repairs, or what is technically termed "darning," I first pick up the margins of the depressions, to the depth of an inch or two, and then flush up with stone broken to pass through a 2-inch ring; the edges of the patch are then covered with road grit, obtained at hand and pounded with a rammer. In these repairs it is found that the horses' feet avoid the fresh stone, while the wheels of the vehicles run over the

patch and compact it gradually from the edges to the centre and a very good "mend" is thus made.

In reading over Mr. North's valuable collection of short histories of road making, I was particularly attracted by the mention of ramming, on page 103. There is a short mention of a rammer 8 inches diameter, weighing 70 pounds. Although steam rollers are far more satisfactory than horse rollers, it seems to me that a still further improvement may be made by the more general introduction of the rammer. In all cases of roads, whether Telford or Macadam, or stone paving, or wood paving, the first imperfections are the same; the surface may not be worn away materially, but there are depressions or concavities that hold water. Our block stone pavements get into bad order chiefly through unevenness, and a heavy expense is incurred in repairs, while the hollow parts are found to be hard and well set, and the blocks not worn, perhaps, any more than those forming the better parts of the road. A wooden pavement on one of our streets was condemned for being in hills and hollows; although incidentally there were rotten blocks that broomed and wore away, it was found, on taking it up, that the foundation was uneven, and this notwithstanding that it had been steam-rolled before the blocks were laid on, five years before. All this tells the same tale; the earthy foundation is of unequal density.

Much more attention has been paid to the coating of stone or other material than to the lowest or earth foundation. When a new road is made, the proper form may be given to the earth foundation, and it may be steam-rolled; inequalities then showing themselves may be flushed up and re-rolled, but a roller will bridge over smaller soft places which still remain unseen until the road is completed and heavy traffic put upon it, and then we have saucer-like dips in its surface, to be repaired within a short time after the road is made; and although the specification may require that these repairs shall be done by the contractor, the surface being thus broken, the road is never so good afterwards as it would be if undisturbed.

How the rammer which Mr. North refers to was used is not mentioned; but if by steam power, it might be neither expensive nor slow.

I am inclined to think that the regular stroke of a rammer is the only method of producing equal densities for roads, as well as for other purposes, and that the most important part of road making for its application is the earthy bottom.

After the ramming to equal density, I cannot see that Telford's method is better than Macadam's for general adoption; local circumstances, however, would decide in each case.

After reading through all the various descriptions, and adding my own views from observation and experience, I consider the object to be aimed at is as near as possible, a solid bed of stone. This certainly cannot be accomplished by putting on any earthy matter as binding. Broken stone in thin layers, 3 to 4 inches, chinked with fine chippings or screenings until full, and then watered and rolled with steam roller, will come very near the desideratum. Of course the lower strata may be of stone, less hard than the top. The size of broken stone for the upper part is important. A 2½ inch ring allows stone of considerable size to be mixed with lesser ones, and it is these larger ones that first get loose and move about on the surface. For the surface coating I prefer hand broken stone over machine broken, as the form is generally more cubical and less apt to become disintegrated.

Gravel is much more difficult to reduce to solidity than broken stone; but where there is a large supply, and cheap, it is well to follow the principle before mentioned. The gravel should be screened, and the coarser sort laid on first and then chinked up with the finer. If this is done, and all coarse gravel kept away from the top coating, water and steam rolling will make a good road in almost any case without earthy binding. Earthy matter works into mud, and should be avoided, unless the gravel is so round and movable that nothing else will keept it quiet.

Where old paving is taken up, and it is proposed to put down Macadam, I consider that there is the same necessity for testing the density of the foundation, and rendering it equal by ramming.

A. B. Hill.—In New Haven we have tried several plans in regard to the binding material of the Telford pavement. Using an inch of loam on the crushed stone, with two inches of screenings over that; also using sand instead of the loam; but the best results with us are obtained by using the trap rock screenings alone, spread on in thin layers, sprinkled and thoroughly rolled. This makes a very solid, firm surface, which does not wear into ruts as soon as the pavements top-dressed by the other methods. The roller used is the 15-ton Aveling & Porter.

As the grades in New Haven are generally very light, and it is desirable to secure a uniform, smooth gutter, the latter is made of blue stone, 12 inches wide and not less than 4 inches thick, bedded in sand

next to the curb, closely jointed, well rammed, and, after the pavement is complete, thoroughly grouted.

A space of three feet outside the gutter stone, between the rails of the horse railroad tracks, and for three or four feet outside the rails, is laid with stone blocks.

The Telford pavement is 16 inches thick at the centre and 14 at the the sides, made up of 4 courses of trap rock; the first or bottom course 7 inches thick at the centre and 5 inches at the sides; the stones of the size and placed as usually specified for Telford foundation; the second course, 3 inches thick, of stone simply raked out and sorted at the foot of the trap dikes (not "broken" or "crushed"), varying in largest dimensions from 1 inch to 4 inches, spread on the first course and rolled until solid; the third course, 4 inches thick of "crushed" stone, also rolled; the fourth course, or top-dressing, about 2 inches thick of screenings, spread on in three layers, each layer sprinkled and thoroughly rolled in.

The average cost of the Telford pavement in New Haven, including the Belgian blocks, blue stone gutters, crosswalks, inspecting, rolling, &c., was, for 1876, $1.18 per square yard.

" 1877, 1.05 " "
" 1878, 1.15 " "

Charles Douglas Fox, of London (through the Secretary).—There can be no doubt that the present system of consolidation of the Macadam is very imperfect, even when a steam roller is employed. I am of opinion that a better result would be attained if a really good steam rammer or stamper could be devised. At present the roller leaves the upper stones in a very loose and disintegrated condition. Our Victoria Embankment, upon which no expense was spared during construction, seems to be in constant need of repairs, and this although steam rollers were employed.

A really good pavement for cities remains to be discovered, which would fulfill properly the economical and sanitary conditions, and at the same time be noiseless and safe.

Asphalte soon wears out, and is very dangerous when damp, but not very wet.

Wood pavement is difficult to clean, and allows the substratum to become saturated.

E. Lavoinne, Engineer des Ponts et Chaussées, France (through the

Secretary).—The criticism of Mr. North upon the Macadam roads in the City of Paris, is to the effect that owing to the method of compacting, sufficient stability is not given to the stones to resist the traffic. Mr. Malo is quoted as sustaining this criticism. Even if the bad results in Macadam pavement in Paris were something like what Mr. Malo describes in his rather sweeping remarks, the fair inference would be, it seems to me, that the system of construction was not the best in that location on account of the heavy traffic.

Macadam roads when introduced in Paris to replace the former pavements were considered by many engineers as a blunder on account of the cost of their maintenance and other peculiarities. It is certain that no Macadam road, even if constructed under the best conditions, could stand the enormous traffic existing in many streets, which is not occasional as Mr. North states is the case for some of the Boulevards of New York, but continuous and daily for most of them.

As regards the construction of roads, the illustration of what Mr. North calls the French system, such as he saw applied in the repairs of some streets in Paris, hardly gives an exact idea of the standard system adopted by many French Engineers. They generally consider that in a perfect Macadam all stones should bear directly against one another by faces as large as possible, not by edges, and that the interstices, previously reduced to a minimum by rolling should be filled afterwards with a binding which cannot be affected by atmospheric influence nor give access to moisture. Thus far they agree with Mr. North—but they disagree with him as to what is the best binding.

Instead of screenings or very small stones with the addition of dust and water, they prefer to use sand with a small quantity of chalky dust employed when compacting is at an end. They consider, contrary to Mr. North's theory, that when the stones, whose sizes vary between 1½ and 2½ inches, have been thoroughly packed together by rolling before any addition of binding, so that they move no more under the roller, and a beginning of crushing takes place, then an addition of smaller stones is useless for stability; if very small stones like screenings were then added, they would be crushed and produce an excess of dust injurious to general stability. Sand, injected by thorough watering between the stones is not liable to that objection, since, filling all the interstices it tends to equalize the pressures between the stones. The addition of chalky dust diluted by water, at the end of the operation, fills the inter-

stices between the grains of sand making with it a sort of mortar and coating for the surface. In my own experience the best results followed this method ; the consolidation of the Macadam was very satisfactory at the end, rolling not being spared before the addition of binding. Loose stones occurred only at a few points.

It may be that the roads examined by Mr. North, in Paris, were constructed in too thick layers and too hastily to permit the stones, prior to any addition of binding, to have the required stability, much rolling being necessary for this result. This may be the reason why loose stones were seen. If the stones have not been packed and wedged previously by thorough rolling, we cannot expect binding to make them immediately compact.

The system mentioned as used in New York (St. Nicholas Avenue), in which stones of from 1 to 1½ inches are employed for the top course will, no doubt, do for light travel (light, not heavy carriages); but such pavement would very likely be destroyed by a heavy traffic, as the small stones would then be rapidly ground and disintegrated. From my own experience and that of many engineers in France, I am fully satisfied that the capital difference between the roads in the old Macadam style without rolling, and those that are rolled, whether with steam or horse power, is the degree of internal wear ; as the grinding of the stones by their reciprocal friction or internal disintegration is much more rapid under heavy traffic with the former than the latter. In the first case the proportion of disintegrated material, detritus, to the stone is generally large after a short time ; very small in the second if proper care has been given to the work.

Evidently much more consideration should be given to the internal wearing which is of serious consequence as to cost of maintenance than to the incomplete consolidation of the road immediately after rolling which could be remedied by more rolling or made up afterward by the traffic itself and by removing the excess of binding material by sweeping.

In conclusion it is suggested that for a fair comparison between the different systems of constructing the roads, there should be taken into account, both the quantity and quality of the traffic, and also the cost of maintenance under the same conditions for a fixed period. Conclusions might be different if full consideration were given to these points.

E. B. Van Winkle.—I would say that I am familiar with the roads Mr. North has been constructing for the past few years, that is, with their

present condition, and should like to ask Mr. North if their present condition bears any relation to the amount of rolling he put upon them; for instance, the Southern Boulevard, which I now consider to be the best of these roads, and the one that carries the greatest traffic, did that receive the greatest amount of rolling?

E. P. NORTH.—The Southern Boulevard received 0.859 ton miles per square yard, or 5.177 ton miles per cubic yard, which is more rolling than any other road constructed by me had, and more than any road known to me has had applied to it.

The road has stood the wear very well, though part of it is exposed to a very constant breeze from the Sound, which deprives it of the protection that a layer of dust would afford.

The teams on it were counted from 8 A. M. to 5 P. M., and averaged about 300, from four horse teams, with six or seven tons to the load, to buggies.

E. B. VAN WINKLE.—Next to the Southern Boulevard I should place the streets constructed by Mr. North in the following order as to degree of excellence, always judging by their present condition:

1st. One Hundred and Thirty-eighth street; 2d. One Hundred and Sixty-seventh street; and last, Mott avenue. Please, if possible, state which of these received the greatest amount of rolling, and if there were any differences in the quality and size of the metal and the material used for binding.

E. P. NORTH.—One Hundred and Thirty-eighth street which has two courses of broken stone, each about 6 inches deep before rolling, received less rolling than the Southern Boulevard; the surface is satisfactory except in one place, where the bottom was bad and mud worked up through the metal where there are some loose stones. One Hundred and Sixty-seventh street is on a heavy grade, part being at the rate of $11\frac{2}{10}$ feet per 100, and the rest with 8 per 100 for a maximum. The first was rolled with both horse and steam rollers. The steam roller ascending by an easier grade. Some clay hardpan was used here in connection with the screenings, both to increase the adhesion of the roller wheels and facilitate the compacting of the road bed. The roller, a 15-ton Aveling & Porter, old pattern, ascended the grade after the application of the hardpan. On the lighter grades nothing but screenings was used for binding and the rolling was done entirely by steam. This part of the wheelway wears much better than that portion where hardpan was

used. No reliable account was kept of the amount of rolling this street received.

The circumstances under which the wheelway on Mott avenue was constructed are fully detailed in Transactions Vol. VIII, page 110 (May, 1879). On account of its treacherous bottom it probably received less rolling per square yard than any other road, though it was impossible to keep accounts of the amount of rolling done.

All of these streets are Macadamized with two-inch trap and clean trap screenings, excepting that portion of One Hundred and Sixty-seventh street, mentioned above.

B. F. Morse:—The paving of the Cleveland Viaduct, west of the river, over the arches, is laid with New York Medina sandstone; the roadway is 42 feet between curbstones, with a double track street railroad in the centre.

The ballast used was of the best quality of bank gravel spread in layers of about five inches in depth. Each layer was sprinkled with water and rolled. The last layer or that directly underneath the stone, was about two inches deep, and was left without sprinkling or rolling to receive the bed of the paving stones. The surface of the ballasting was finished to the true crown of the roadway.

The pavement is laid with blocks, dressed nearly parallel on top and bottom, sides and ends, laid in courses transversely across the roadway. The courses were from three to four inches thick, and from six to seven inches in depth, and the stone from seven to twelve inches in length. The stones were set close together, so that no joint was more than one-half inch open for at least two and one-half inches down from the top surface.

No gravel or sand was placed between or on top of the pavement while it was being laid. After the stones had been set in place in sections of fifty to one hundred feet in length of the street a light top dressing of gravel or sand was spread over the surface and swept into the joints with a steel splint broom. The pavement was then thoroughly sprinkled or flooded with water. Then the pavement was thoroughly rammed two or more times with a paver's rammer weighing about ninety pounds; then the pavement was again washed or flooded and allowed to dry off.

The joints were then filled to a depth of three to five inches with a concrete composed of Trinidad bitumen and coal-tar cement, distilled at a

temperature of not less than 600 degrees Fahrenheit, and mixed in proper proportion, so as not to soften or become brittle under heat or cold, and was poured into the joints of the pavement at a temperature of not less than 300 degrees, and then the whole surface was covered with one-half inch of fine gravel or sand, which completed the work.

The pavement on the fixed iron spans was laid in the following manner: Strips of oak plank varying in thickness from one and a half to three inches were secured to the iron floor beams, running longitudinally, to give the proper crown to the roadway. On top of these longitudinal floor beams was laid a layer of two and one-half-inch plank, joints well broken and spiked down. On top of this layer of plank there was laid two thicknesses of tarred roofing felt, or paper laid in hot roofing cement, and the whole covered with one-fourth of an inch of plastic pitch, and over this was laid a layer of inch boards or sheathings, breaking joints with the plank underneath, and thoroughly spiked down.

The paving is what is usually called "Nicholson," and consists of blocks four inches long and three inches thick laid upon and in rows across the roadway with a three-fourth-inch strip, one and one-half inches in depth between the rows of blocks, and nailed to the flooring, the blocks breaking joints at least two inches with adjoining row. The space between the rows of blocks was then filled with concrete, composed of one part of hot undistilled gas tar to two parts of pitch, mixed with clean lake sand and fine gravel, applied hot and driven into the joints with an iron blade and heavy rammer, until the spaces were even full. The whole surface of the paving and gutters was then coated with a top dressing of coal tar, pitch, and fine gravel, rolled thoroughly with a heavy hand-roller. The best quality of seasoned white oak was used for all the wood parts of the pavement and plank floors.

E. S. Chesbrough.—I cannot state the average wear of wood pavements; I can only state that it differs very much with regard to different kinds and in different localities. You can easily see that very much depends upon the faithfulness of doing the work and the material used.

In some cases in Chicago wooden pavements have lasted ten years, and even longer; and in others they have become very rough and uneven in three or four years. I am not able to give the precise average, but of course a great deal depends upon the traffic. In the river tunnels the wooden pavements have worn out in less than two years, and where the wheels were confined very much to the same tracks they make ruts in

a short time. In other cases, where the streets are broad and clear, and the traffic is spread over a large space, they have lasted a long time; in some cases ten years. It is impossible to give the rule in regard to that unless you take into account various circumstances.

EDWARD R. ANDREWS.—I would like to ask Mr. Chesbrough whether a Chicago there is any very perceptible wear in wooden pavements until decay sets in?

EDWARD S. CHESBROUGH.—Decidedly; I have seen some worn down more than two inches without any apparent decay.

EDWARD R. ANDREWS.—Mr. North states that a well made Macadam road constructed with trap rock is, after an earth road, the pleasantest and safest known. But trap rock or other really good materials for making Macadam roads are not available everywhere, and at best Macadam roads are only adapted for pleasure travel in parks or suburban towns, where they can be constantly watered and never allowed to get out of repair. Macadam is not adapted for general use in cities. Under heavy traffic, the surface is constantly ground into powder, which rises in dust in the summer, and they are very muddy in the winter. Even in Paris, where the maintenance is most thorough, the streets being continually watered in summer in the manner described by Mr. North, and frequently washed after a day of unusual wear, and scraped by a large army of cantonniers, yet, after heavy rains, the mud is frequently nearly ankle deep, and in very hot weather during the intervals of watering, or in frosty weather, the air is filled with most penetrating dust. Mr. Flad describes the same state of things in St. Louis; and, in Boston, when, in winter, there is no snow to cover the ground, and on account of the cold, the streets cannot be watered, the dust is intolerable; and in summer where, for economy's sake, watering is neglected, a large part of the material, with which the roads are made is blown into the sea.

The Compressed Ashphalte, so common in London and Paris, when constructed as thoroughly as it is in those cities, and as that on Fifth Avenue in front of the Hotel Brunswick has been, is a most excellent pavement, but it also demands the most careful maintenance. No dirt should be allowed to accumulate upon it. In frosty or in damp weather, coarse sand or fine gravel should be spread over the surface to give a good footing for horses. This is done abroad, and then it is not slippery; it is very quiet, and in fact has almost all the qualities needed in a perfect pavement, but it can only be laid on levels, and is expensive.

Stone Block Pavements are in many parts of the country the cheapest, and possibly may be the best where the traffic is very heavy, but it is emphatically the worst pavement for streets of residences or wherever quiet is desirable; and there is no question but that if the incessant din from the rattling of omnibuses, heavy teams, milk wagons, &c., from which one suffers in large cities paved with stone blocks, could be dispensed with by adopting a quiet pavement, the length of life of citizens would be increased and the general health improved. Such would have been the case long ago in New York, had it not been that the wooden pavements laid during the "Tweed" days were such evident jobs. In London, wooden pavements give entire satisfaction. The earliest were not quite successful, but the defects in construction have been remedied, and now broad areas of heavily worked streets previously paved with stone are being laid with wooden blocks, which are found to wear satisfactorily.

In the West, where stone for pavements cannot be had, wooden blocks are largely used; but, as wood is cheap and can be replaced without much expense, no sound principles are followed in their construction. In the Eastern States, no one will allow that a wooden pavement can be good except when newly laid, when all agree that it is delightful. There seems to be an unwillingness, even among engineers, to give the subject the attention it deserves. All agree that stone pavements are a curse, and that it would be a blessing if a good substitute could be found, but because wooden pavements, as they have been made here, have not been a success, condemn them as a class.

Mr. North has stated what has been the general practice in laying wooden pavements in this country. Many methods have been tried, but they have almost without exception been "laid with *green* or wet blocks, more or less thoroughly dipped in tar, on a bed of sand, not always well rammed, with or without the interposition of a tarred pine board, with transverse joints from one to one and a half inches wide filled with gravel and coal tar," and I might add, the whole done in a most unworkmanlike manner.

The results are what might have been expected. The careless manner in which the joints have been filled, has left many channels open for the admission of water, which undermines the sand foundation, so that there is an uneven subsidence under the passing wheels, and holes, small at first, but daily growing larger, appear, so that the surface is

soon destroyed. The result is but little better when tarred boards are laid under the blocks. This practice of tarring wet, sappy boards and blocks seems to be an invention to make them decay as soon as possible. It closes up the cells of the wood, so that the moisture cannot escape; fermentation immediately follows, which quickly destroys the strength of the fibres and reduces them to punk. A pavement, constructed in this manner, would fail of course. Thoroughly seasoned wood might be benefitted by the tarring process, but green wood never.

Observe how differently wooden pavements are constructed in London. Mr. North describes several methods, either of which is vastly superior to any of the patented systems used here. A rigid foundation of bituminous or cement concrete is universal. This costs more than sand, but it is permanent, and will prevent the blocks from sinking under the wheels. English engineers, in discussing pavements, call the foundation the true pavement, the blocks being the wearing surface only. The "Henson" pavement, with some modifications, strongly recommends itself to my mind as the best for this country. Instead of a layer of tarred paper on the concrete, I would use a thin layer of pitch, with oil enough in it to make it permanently slightly plastic, setting the blocks upon it while hot and soft, using the strips of tarred felt between the rows, and driving the blocks together as described by Mr. North. The tarred felt would make a very close joint. Then pour melted pitch over the whole surface, taking care to fill every crevice, and upon this spread fine sharp gravel, which will work into the ends of the blocks and form a surface resembling macadam, and afford a far better footing than wide spaces between the rows, which serve as receptacles for mud and dust. It is easy to keep this pavement clean. No water can penetrate it, so that it will not be injured by frost. The blocks themselves, if creosoted, will not absorb water, and if laid without spaces between the blocks, the drainage will be surface drainage solely, which is of the first importance.

But the pavement would be short-lived, if *green* and wet blocks are used. It is not practicable to use, as Mr. North says is the case in London, "wood better seasoned than the pine generally used by house carpenters in this country." Seasoned wood cannot be obtained in sufficient quantities here. But, what is far better, it can be preserved from decay. I have no faith in any method of wood preservation for paving blocks, which does not exclude water. The blocks are so short, that any soluble

preparation is quickly washed out of them, and, if not made waterproof, they are certain to absorb the seeds of destruction from the filth in the streets. The blocks should be well saturated with creosote oil, whose chemical constituents act preservatively upon the fibres of the wood, by coagulating the albumen of the sap, while the fatty matters act mechanically in obstructing the pores of the wood and keep the water out. At the same time, as oil cannot be injected into wood full of moisture, the thorough artificial seasoning, which forms a part of the process of creosoting as carried on in this country, is as useful to the timber as any of the metallic salt processes.

By thoroughly creosoting the blocks, expansion and consequent throwing out of the blocks is prevented. They will not shrink or expand. The wood is also rendered homogeneous; the sap wood becoming as durable as heart wood. Looking to sanitary considerations, the creosoted wooden pavement is perfect. The carbolic acid contained in the oil is a powerful disinfectant, and as the pavement described will not absorb any deleterious substance from the surface, it has only to be kept clean to maintain the best sanitary condition. This is far from being the case with wooden pavements laid on the American plan. They soon become a mass of decaying vegetable matter, and, as their powers of absorption increase with their disintegration, they become filled with corruptible matter absorbed from the filth of the street, and as their surface becomes filled with holes, it is absolutely impossible to keep them properly clean.

A good wooden pavement is also an inexpensive one. The cost, including a cement concrete foundation, 6 inches deep, would not exceed $3.00 per square yard. The system of maintenance adopted in London, of making it a part of the contract of construction, would insure good workmanship in laying the pavement, and a good permanent roadway afterwards. It would not be difficult to find responsible and honest contractors willing to take such a contract at a fair price.

In considering this subject, one should not overlook the statistics of accidents gathered in London by Col. Haywood,* which show that a London horse will travel on granite 132 miles, on asphalte 191, and on wood 446 miles, before an accident occurs.

The actual wear of wooden blocks is very slight, as long as the fibres of the wood are sound. Mr. North states that it is $\frac{1}{8}$ of an inch per

* See full reports in the library of the Society.

annum in the streets in London, with the heaviest traffic. Mr. Geo. Frederick Deacon, Member Inst. C. E., in a paper read before the Inst. of C. E., states that, in Great Howard street, Liverpool, which is a shop street, with a traffic consisting chiefly of carriages, amounting to about 94,000 tons per annum per yard in width, the pavement was worn to the extent of $\frac{3}{8}$ of an inch in four years. This would give a life of nearly twenty years before the blocks would be reduced from 6 inches to a thickness of 3 inches, which is still sufficient to maintain the blocks in place.

In Oxford street, in London, where the traffic is equal to 300 tons per foot per day, the amount of wear has been found to be from $\frac{1}{16}$ to $\frac{1}{8}$ inch during three and a half years. This street is laid with the Henson pavement. This slight wear is largely due to the fact that the ends of the fibres do not broom, and thus retain their original strength.

C. Shaler Smith.—I merely wish to ask Mr. Andrews—speaking of the foundations of wooden pavements, if he is aware of any pavement being laid as upon the Cleveland Viaduct, that is, Nicholson pavement upon an iron foundation?

E. R. Andrews.—I am not aware of any except the Broadway Bridge in South Boston, where it was necessary to have a light pavement. A bituminous concrete about two inches thick was spread on the top sheeting and allowed to become solid; then a thin coating of hot tar spread evenly, and creosoted spruce blocks, injected at my works with 12 lbs. of oil per cubic foot laid in rows $\frac{1}{2}$ inch apart, and the insterstices filled with pitch and the surface spread with gravel.

G. Bouscaren.—Can you give the cost of creosoting?

E. R. Andrews.—$12.00 to $16.00 per thousand feet, board measure.

G. Bouscaren.—Can spruce be treated well?

E. R. Andrews.—Spruce does not absorb oil readily on account of the compact character of its fibres, yet it will take in a gallon of oil per cubic foot; hemlock, pine, both white and yellow, and porous oak, are more absorbent. Wood which is the most destructible, because it absorbs water readily, is really the best for creosoting, as, for instance, the gums and cottonwood.

G. Bouscaren.—Have you any special rule for determining the amount of carbolic acid in the oil?

E. R. Andrews.—I have not taken any pains to ascertain. The quantity depends upon the character of the coal from which the gas

was made, varying from 5 to 10 per cent. It has been ascertained, however, through careful experiments by a Belgian chemist, that the wood-preserving qualities of creosote oil are due rather to the water-proofing imparted to the wood by the hydro-carbons contained in it than by the carbolic acid. The latter is very volatile, and were it not retained by the gummy, resinous oil would quickly escape into the air. In England no reference is made to the quantity of carbolic acid contained in dead-oil to be used in the specifications for contract work. Carefully conducted experiments of my own with pieces of yellow pine, 8″ x 8″ and 9 feet long have shown, that six months after treatment they did not absorb any water during a soaking of 48 hours under water.

M. Merriwether.—We made in Memphis, in 1867, what has proved to us a very costly experiment in wooden pavements. We laid there in that year and the succeeding spring; some 225 000 square yards of what is known as Nicholson pavement. The streets on which this was laid rise six inches from the side to the centre of the street. Two inches to two and a half of sand were laid down, and that covered over with an inch board longitudinally. Those boards were immersed in hot coal-tar. After that were laid cypress blocks eight to twelve inches long, with a thickness of three inches, with a cleat between them, tacked to them. About one-half of that kind were immersed in boiling tar. According to the contract it was to be red cypress wood, which is very durable above-ground, and of more than ordinary durability underground, and is found to last better than ordinary oak; but the sap portion of that wood is very perishable, rotting within one or two years if exposed above-ground. The heart will last twenty-five years, or so, in fences. I mention this to show the durability of the material. Most of that was entirely covered with boiling coal-tar and small gravel, and the interstices filled with sand, making a beautiful pavement for about three or four years. Some portions of it, however, began to show decay in three years, where the sap of the block was put in. The contractor got in a good many sap blocks, and as soon as they began to decay the adjacent blocks were loosened, so at the end of about five years it was in many places impassable, and some blocks were entirely destroyed. The remnants of that wooden pavement of 1867 and 1868, are now there. The pavement cost us $3.89 per square yard. I am satisfied had the blocks all been heart cyprus it would have been good for perhaps ten years. We have portions of the pavement now where the heart of the cypress was used, where there is no sur-

face wear perceivable. However, we are satisfied with that experiment, and I do not think we will ever put down another square yard of wooden pavement of any sort. We are now making arrangements to pave with granite.

E. R. ANDREWS.—It seems to me very clear that the reason why the cypress pavement did not last was because the blocks were dipped in tar. It is not at all probable that these blocks were perfectly seasoned, because seasoned lumber cannot be found in this country for paving purposes, hence the sap enclosed within the wood by the tar soon fermented and the fibres rapidly decayed. If the blocks had been laid without being dipped in tar I think you would have had a very fair pavement now.

I would like to ask as to the condition of a pavement in Washington called the Flannigan pavement, with cypress blocks sawed from round sticks and laid promiscuously, large and small together, the spaces being filled with pitch. I have understood that that pavement has stood well.

J. E. HILGARD.—That pavement has done the best of any in the city. It was tried as an experiment on Third street, near the railway.

The city of Washington has made very extensive experiments in the matter of wooden pavements. Nothing was done to preserve the blocks. They were hemlock; none of it has lain in tolerable condition over four years; much of it had become intolerable even before that time. I think the work was badly done from there not being proper supervision. An immense amount of work was undertaken to be done within a limited time. It was the most disgraceful failure of wooden pavements ever known, and it has been a case of unprecedented decay. None of the streets were in a fit condition to travel over after four years; most of them have been replaced by concrete pavements. With us the experiment has been a very expensive one. Climate may have had something to do with it, for it is very warm in summer and we have very frequent showers, but certainly the decay was unusually rapid.

E. R. ANDREWS.—In 1869, Columbus avenue, in Boston, was paved with wood; every one who had any patent pavement was allowed to put down a piece; one section was laid with creosoted blocks, but very imperfectly prepared. All the pavements were taken up and the street repaved with the Trinidad bitumen in 1877; but a small delta of the creosoted pavement was left, which is still sound and in good condition.

M. MERRIWETHER.—I did not mention that about one-half of the pavement of which I spoke, was laid with planks dipped in boiling tar, and after making about one-half of it the very difficulty suggested by Mr. Andrews arose, and we ceased to immerse the blocks, upon the theory that if the under side was covered with tar it would cost more, so they stopped that process and laid the balance in the other way, and after the planks were down they covered the surface simply with coal tar, upon the theory that the bottom of the planks, not being concealed, the acid would go down; but we did not discover that it made any perceptible difference. It would probably have been satisfactory if the blocks had been heart wood, but the sap of the blocks decaying, led to their destruction by the wheels passing over it. It was an utter impossibility to have seasoned wood for such an extent of pavement—some 225 000 square yards, laid at once. The wood was not in the market, and no one could afford to keep such a stock on hand. The result was that the wood was brought directly from the mills and put down within two or three months from the time it was taken from the stump. I do not think any process short of thorough seasoning, or some process of drying quickly by steam, would do any good. We found it impossible to get the heart cypress entirely, and the sap wood would decay in two or three years.

The blocks covered the surface and prevented the water passing down, but it may have passed on the side. They merely covered the surface with tar, and some little water might find its way down the side of the block. The spaces between the blocks were thoroughly rammed with small gravel, with sand with it, and the surface covered with coal tar.

C. SHALER SMITH.—I have recently made some experiments for the St. Louis Bridge, which illustrate in a marked degree the action of these preservatives depending on carbolic acid for their antiseptic value. Finding the wooden stringers of this structure beginning to rot at the ends and other points of support, while the remainder of each stick continued sound and untouched by decay, I tried to arrest the rotting by the injection of creosote containing ten per cent. of carbolic acid into all these timbers which showed signs of decomposing fibre. The effect was remarkable. Sound wood was unharmed, but where decay had already commenced the acid seized upon the wood and converted all parts affected by rot into a brown cinder, in many cases absolutely destroying

the bearing value of the stick. The experiment was extensively and exhaustively tried, and I am satisfied that while creosote is excellent when properly applied to perfectly sound lumber, it will not arrest decay when once started, and in many cases will destroy all the unsound parts of a stick.

And also, that in the use of creosote, the proper proportion of carbolic acid is a very important element, and should be fixed by specification whenever this system of treatment is used. I have likewise continued experimenting on other methods of preserving wood, three of which have given good results.

The first is the "Thilmany, old process." This consists in impregnating the wood with sulphate of copper, and subsequently with the chloride of barium. The chemical action of the two salts fills the pores of the wood with the preservative chloride of copper, mechanically fixed in position by the insoluble salt, sulphate of baryta.

The second is the "Thilmany, new process."* Here the first impregnation is sulphate of zinc, the second chloride of barium, and the resulting salts, chloride of zinc fixed as before by sulphate of baryta.

The third is known as the tan-zinc process. The first impregnation is with chloride of zinc dissolved in a solution containing 2½ per cent. of glue. This is followed by an injection of a tannin solution which precipitates the glue, forming tannate of gelatine, a perfectly insoluble compound, and which fixes the chloride of zinc so thoroughly that it cannot be extracted either by boiling or steaming. I am not now prepared to state which of the three processes is the best, as our experiments are still going on. It may be safely asserted, however, that no system of treatment depending on a soluble salt, as in the Burnett or Boucherie processes, is of any value unless the salt is fixed in the wood by a subsequent injection which will fill the pores with an insoluble substance. I have procured specimens from various Burnettized bridges, and the analysis has shown in every case that the zinc had been entirely washed out of the wood. In treating wood by either the creosote or metallic salt systems the antiseptic injection is virtually worthless unless the wood has been previously deprived of its sap. In doing this the following rules should be rigidly observed.

First.—The steam bath should not exceed 5 pounds pressure, or 240° F. in temperature, and the lumber should remain in the bath for not less

* For specifications of this process, see Appendix No. 6.

than 90 minutes for sticks under ten feet in length, and 9 minutes additional for every additional foot of length.

Next.—The steam bath should be followed by an exposure to a vacuum of not less than 11 pounds pressure for 40 minutes for sticks less than 10 feet in length, and 6 minutes more for each additional foot, after the vacuum is reached.

Last.—The preservative injection should be run in while the vacuum is still on, and after the cylinder is filled the injection pressure should be brought up gradually to not less than 100 pounds. The time for its continuance will vary with the wood used and the length of the stick.

By the observance of these rules in treatment and the selection of thoroughly sound lumber, it is in my opinion perfectly practicable to produce a good wooden paving block, which, when properly laid, will make a clean and lasting pavement. Treated gum blocks placed in the testing machine at the St. Louis Water Works stood the passage of 95,000 wheels with a wear of only one-eighth of an inch. The wheels of testing machine were loaded to 2,000 pounds per wheel or 800 pounds per inch of tire width.

It is hardly necessary to reiterate, however, that no system of treatment, however good, will arrest decay, convert unsound blocks into sound ones, or render blocks cut from dead trees fit material for a pavement.

Edward R. Andrews: I do not wish to advocate the use of decayed timber, or to intimate that by the process of creosoting, wood which has lost its quality by reason of decay can be restored to its original strength; but if partially decayed timber be creosoted the process of decay is arrested, and there may be cases where it will be advisable to creosote it, and thus save for future usefulness timber which would otherwise be valueless.

As an instance of such an experiment, I quote from the *Journal of the Society of Arts*, London, June 1st, 1860, containing a paper by G. R. Burnell, entitled "On Building Woods, the Causes of their Decay, and "the Means of Preventing it," and a discussion thereon by the members of the society, during which Mr. John Bethell made the following statement (see page 565).

"That in timber where decay had commenced it had been stopped by "the injection of creosote. He could confirm that fact by stating that "about twelve years ago many thousand sleepers were packed upon the

" Lancashire & Yorkshire Railway some time before being used. When " they were about to be used they were found to be more or less decayed, " and it was a question whether the whole should not be sold for fire- " wood, when it was determined to submit the sleepers to the process of " creosoting. After those sleepers had been down for ten years it was " found that not only had the decay been arrested, but the sleepers were " as good as if they had been sound, new timber."

I do not quite approve of General Smith's specifications for the treatment of timber. Unless he has positive proof to the contrary, I should doubt whether large-sized timber can be properly dessicated in ninety minutes. In my own experience I find that the time required is greater with large timber than with small, and in proportion to its square rather than its length. Wood is a slow conductor of heat, and a 12" by 12" stick cannot be heated through to a point of vaporization in ninety minutes, and the moisture cannot be withdrawn until it is vaporized. Moreover, it will require a vacuum of 20 to 25 inches during several hours to withdraw the vapor, so that danger of decay from moisture within the wood shall be removed. If this is not accomplished before injection with creosote, the effect will be to close up within the wood fermentable substances. Thorough injection cannot be effected. The incompressible water will not permit the oil to permeate those portions of the wood where it exists.

Engineers should give time enough to do good work. In the practice abroad and in this country, where creosoting is done intelligently, the work is never hurried. Large piles and square timber cannot be properly dessicated and creosoted in less than from 20 to 24 hours. Such work costs more money, but is cheapest in the end. Paving blocks can be treated much more rapidly. During the infancy of creosoting in this country great care should be taken to secure thorough work in order to obtain for such timber the longevity attained in Europe and the confidence of consumers.

David E. McComb—I shall confine my remarks to granite and bituminous pavements as laid in the cities of Washington and Georgetown, D. C.

The standard stone pavement has a base of six inches of hydraulic concrete, upon which is spread three inches of sand, in which the granite blocks, measuring eight inches by four inches by six inches in depth, average, are bedded with close joints, which joints are filled with

screened gravel, pea size, heated to a temperature of 400° F. The blocks are then brought to a solid bearing by the use of the ordinary rammers, after which the joints are filled with coal tar refined to 400° F., which removes the light oils, water, &c., yet retains the heavy oils, "cut back," which is the result of a mixture of the residuum of the destructive distillation of coal tar, with still bottoms, being carefully guarded against. After the joints have been filled with the tar as before described, fine heated sand or perfectly pulverized limestone is spread over the surface, which completes the pavement. In situations where the sub-foundation is solid and unyielding the concrete base is dispensed with, six inches of gravel compressed by a heavy steam roller being substituted in its stead.

All the different kinds of tar pavements have been laid and tested in Washington, and our experience is that they are not economical, requiring too extensive repairs and too frequent renewals.

The only two pavements that have given any reasonable degree of satisfaction are those having a mixture of Trinidad bitumen and coal tar refined to 400° F. in approximately equal proportions as the cementing medium of the sand, limestone or other ingredients forming the body of the wearing surface. Such a top coating is good for about seven years, requiring, however, watching and small repairs during this time, after which it seems impossible to patch it successfully.

There have been laid six squares of Neuchatel under two different contracts, the first in 1872, the latter in 1876. That laid in 1872 on I street has stood the test of time and limited travel very well and is in fair condition now. That laid in 1876 on Pennsylvania avenue is in very poor condition, and requires extensive repairs, This class of pavement possesses one fatal objection, viz., its extreme hardness, as a consequence of which, when the surface is covered with a film of water it is only by the exercise of great care that horses can travel upon it without slipping and falling oftentimes, especially in turning corners.

The pavement of this general class that has given the most satisfaction has for its foundation a depth of six to eight inches of hydraulic concrete, upon which is spread a coat of asphalt mastic half inch thick, which is intended to give an uniform surface to compress the top coat upon. This cushion coat, as it is termed, is composed of 62 parts of fine sand, 15½ parts of pulverized carbonate of lime, and 22½ parts of asphaltic cement; all the compression given to this coat is that due to

rolling with a hand roller weighing about ten pounds per inch run. The top coat or wearing surface is composed of 65 parts of fine sand, 16 parts of pulverized limestone and 19 parts of asphaltic cement. The sand is required to contain not more than five per cent. of clay, and to be a little finer than would be usually accepted for use in making mortar; the asphaltic cement is composed of refined Trinidad asphalt and refined petroleum still bottoms, or paraffine oil in the proportion of 100 pounds of the former to 19 pounds of the latter. The pulverized carbonate of lime is mixed, when cold, with sand heated to 300° F., which mixture is then mixed with the asphaltic cement, heated also to 300° F., and a thorough incorporation is effected in a twin pug mill, after which the material is carried in carts, having an arrangement to keep it hot to the work, and is spread upon the cushion coat with rakes, and having a thickness of $2\frac{8}{10}$ inches. It is then rolled with the hand rollers before referred to, the jointings at the curb being tamped with the pilon described by Mr. North, which is heated to a temperature of 500–250 F., the test of its being too hot is that it scorches a white pine plank, on hand for the purpose of trial. The surface is then rolled with a steam roller weighing 300 lbs. per inch run of large disk. No difference is observable between rolling with cold or heated roller. The disks of the roller are kept moistened with crude petroleum, which prevents any tendency to pick up the top coat, and when the proper proportions are observed no trouble is experienced from the machine shoving the material ahead, this occurring when the mixture is too rich in asphaltic cement. After being compressed the thickness of wearing surface is two inches.

The gutters are painted with asphaltic cement ironed in, the object being to prevent the degradation that occurs at this portion of the carriageway, caused mainly by the fact that this portion of the carriageway does not share with the traffic compression produced at the other parts of the roadway.

Trouble has been experienced on pavements alongside of street railroad tracks, the cross ties of which, if not well ballasted, move up and down sufficiently to break the pavement over them and leave ugly ridges. The tendency to cut into ruts alongside of the rail is counteracted by laying granite blocks eight inches by four inches by six inches alternately as header and stretcher bedded in mastic, the toothing thus formed obviating this tendency to rut.

The above described pavement, when honestly proportioned and laid, possesses all the elements which go towards making a good pavement, and it is not expensive, costing at the present time about $1.75 per square yard.

I agree with Mr. North that a bond for maintenance for a term of years should be required from the contractor for this class of work, there being so much of honesty and skill required in refining and manipulating the materials composing it.

E. P. North—.I would like to ask Mr. McComb how much clay is left in Trinidad bitumen and how it is refined.

D. E. McComb—There is supposed to be left in the refined bitumen twelve per cent. of impurities, it being practically impossible to refine it so that it will have a smaller percentage of impurities than that.

Note on the Nomenclature of Bitumens.

BY EDWARD P. NORTH.

While such strenuous efforts are being made for uniformity in the matter of measures, the nomenclature of bitumens should secure attention.

In Paris, and in France generally, the nomenclature of M. Malo and others as given in Transactions, Vol. VIII, page 121 (May. 1879), is used. Colonel Haywood also employs it in the specifications and reports of the City of London, and it is believed that all dealers and manufacturers of asphaltes use the same nomenclature.

On the other hand, in this country dealers in Trinidad bitumen and its mixture, almost invariably call their compounds asphalt or asphaltum. Tar Pavers and roofers also apply the same names to their products, both calling such asphaltes as are capable of compression Neuchatel, apparently because the Val de Travers asphalte happened to have been imported into this country by a branch of the "Neuchatel Asphalte Company, Limited," of London, which bought out "La Societe Generale de Asphaltes de Suisse," but could not take the name Val de Travers as there was at that time an organized company in London bearing that name. Val de Travers asphalte is not called Neuchatel in any part of Europe, besides which there are at least three other asphaltes that can be compressed, besides many others that are used for mastics.

As the distinction between asphalt or asphaltum on the one hand, and asphalte on the other is too slight to attract the attention of any but

a critical reader, the advisability of following Malo's nomenclature is submitted to the Society as the most logical and convenient.

F. RINECKER, of Wurzburg, Germany (through the Secretary).—Besides the methods of paving described in the paper of Mr. North the following may be worthy of a short mention :

Brick pavement, especially in Holland, where very hard brick, *Klinker*, is used for this purpose.

Flag pavement, in many Italian towns, consisting of large slabs, laid in rows for the wheels to run over, the balance of the street being common pavement.

Concrete pavement, which (if I am correct) was tried in Paris and New York. I am ignorant of the results, however. I have seen some sidewalks and depot platforms in Germany, which wear well. For traffic it will be worthy of consideration, whether the broken stone or gravel used in the concrete should not be of the same hardness as the cement to insure equal wear. In using harder stone the unequal wear might be a cause of failure.

In selecting any system for covering roads and streets uniformity is necessary throughout a whole city, at least in its main thoroughfares. The safety of horses greatly depends on their shoes, but the patterns of the shoes differ with the roads on which they are to be used. The connection between shoes and roads needs no comment, and in my opinion it is a grave mistake to use stone in one street and wood in another, when the same traffic has to run over them both.

I attach some notes taken from German and French periodicals, the figures of which I have reduced to United States standards.

As to the cost of some pavements to the square yard, the "*Deutsche Bauzeitung*," 1877, has the following :

	Vienna.	London.		
	Granite.	Granite.	Asphalte.	Wood.
Durability, years,	35	15.6	17	11.34
Cost of construction, $	3.07 to 3.37	3.77	3.80	3.20
Total cost of maintenance, $	1.74	1.40	3.27	3.37
Aggregate cost averaging to one year, cents,	13	37	34	62

From experience at Buda-Pesth the following data for 15 years are furnished :

	Granite on				
	Broken Stone.	Concrete.	Trachyte, on Broken Stone.	Wood.	Asphalte, Comprimé* on Concrete.
Thickness of pavement, inches,	7.1	7.1	7.1	?	2.36 to 2.76
" " foundation, "	6.3	6.3	6.3	?	9.7
Cost of construction, $	4.50	5.05	5.50	3.00	4.35
Total cost of maintenance, $	2.40	1.80	3.00	6.00	3.00
Aggregate cost of 15 years, averaging to one year, cents,	46	45	57	60	49

The paving stones of Paris are described in "Romberg's Zeitschrift f. pract. Baukunst," 1878, as follows:

According to the specifications a distinction is made between large and small blocks.

Large blocks to be 7.9 to 9.2 inches long, 6.3 to 9.2 inches wide, and 7.9 to 9.2 inches high.

Small blocks to be 6.3 inches long, 3.9 inches wide, and 6.3 inches high. The latter, "*paves de petit echantillon*," are preferred of late. Differences in size to 0.4 inch are admitted.

On account of the bond a certain percentage to be blocks one and one-half times as long as specified above, "*boutisses.*"

According to the dressing two qualities are distinguished: smooth and rectangular blocks for joints of only 0.2 inch, and rough ones for joints up to 0.6 inch.

The material is sandstone "*gres d'yvette des Vosges*," or "*de l'Ourthe*," and porphyry from Belgium and Bavaria. This porphyry, however, has not given satisfaction, wearing too smoothly.

The price is $44 to $125 the thousand, and $8 to $13 additional for dressing.

The Macadam is being replaced where annual repairs exceed 50 cents the square yard.

As to the cost of the Paris pavements the following notes are from "Annales des ponts et chaussées," 1877 and 1878:

	Pavement.	Macadam.	Asphalte.
Cost of construction.....	$2.55 to $3.45	?	$1.93 to $2.42
Annual cost of maintenance, cents	9.6	29.0	17.7

* Asphalte comprimé is the French term for the compressed powder.

The wear of Macadam amounting to 23.37 cubic yards to the mile and 100 horses.

Annual cost of maintenance to the square yard :

	1872-75.	1876.	1878.
Pavements, cents	7.7	8.2	8.5
Asphalte, "	19.3	20.9	20.4
Macadam, "	29.0	34.0	32.2

The watering with carts costs—

On Macadam, 19.3 cents to 1 000 square yards.

On pavements, 9.6 " " "

J. B. Dumas, Assistant Engineer of the City of Paris, published comparative estimates in "Nouv, Ann. de la Constr," 1878–79, from which the following data are compiled :

Cost of construction.	Price to the yard.
Pavement of rectangular blocks, "*gres*," 3.9 by 6.3 by 6.3 inches..	$3 22
Macadam of silex	1 61
" " meuliere	1 84
" " porphyre	1 98
Asphalte comprimé, 2 inches thick on 3.9 inches of concrete.	
Using for the latter hydraulic lime	2 93
" " Roman cement	3 08
" " Portland	3 15
Each inch of asphalte above 2 inches additional	1 05
Wood pavement, Trenaunay	2 76
" " Norris	4 31

Annual cost of maintenance and repairs :

Repaving	24 to 64 cents.
Asphalte, roadway	21 "
" crossings	32 "
" sidewalk	4.8 "
Macadam, silex	47 "
" meuliere	55 "
" porphyre	129 "
Wood pavement	56 "

Both systems of wood pavements f.iled in streets with high traffic.

Experiments with asphalte coulé* have shown its unfitness for wagon traffic.

* Asphalte coulé (poured) is the French term for Mastic.

THE ENGINEER, 1878, Vol. XLVI., p. 358, ascribes the invention of the Macadam to John Lochhead in 1794.

J. J. R. CROES.—Referring to the amount of water used for keeping down the dust on Macadamized roads (p. 113), the following may be of interest:

In the year 1872 an account was kept of the water used on the drives in the Central Park in New York city.

The length of carriage ways is 9.435 miles, of widths from 30 to 60 feet, averaging 54 feet. The area occupied, including spaces for carriages in waiting, is very nearly 250 000 square yards. The carts used for watering are in the form of a segment of a cylinder of 35 inches diameter, the height being 26½ inches and the chord 20 inches. The barrel is 90½ inches long, and contains 40.7 cubic feet of water.

During the season of 1872, from April 1st to Oct. 31st, the roads were sprinkled on 136 days, using 81 305 barrels of water, or 3 309 114 cubic feet, an average of 24 332 cubic feet per day, or 97⅓ cubic feet per day for each 1 000 square yards. The greatest amount used in any one day was on July 1st, when the temperature ranged from 77° to 93° F. and 929 barrels or 37 810 cubic feet of water were used; an average of 151¼ cubic feet per 1 000 square yards.

The next greatest amount used was on June 22d, when the temperature ranged from 70° to 86° F., and 890 barrels or 36 223 cubic feet of water were distributed; an average of about 145 cubic feet per 1 000 square yards.

At least one half of the area watered was sprinkled twice as often as the other half, in consequence of its greater exposure and the greater travel upon it.

I am informed that during the summer of 1879 the carriage way of Fifth avenue from Twenty-third to Thirty-fourth street, 0.55 mile in length and 40 feet wide, embracing 12 907 square yards, was kept watered by six carts holding 70 cubic feet each, and making from 3 to 6 trips per day. This would make the amount of water used from 97.5 to 195 cubic feet per 1 000 square yards. The pavement is of trap blocks.

E. B. VAN WINKLE.—Referring to page 95 of Mr. North's paper: The form of roller proposed for the upper layers of earth roads, namely, large and smaller sized disks placed alternately on the axis of the roller, I have seen used with excellent effect on an embankment, and it could

doubtless be so used for the foundation of earth roads, but is unsuitable for surfacing and road maintenance. The ridges left by the use of this form of roller would tend to carry surface water longitudinally instead of the shortest distance transversely to the gutters.

I believe it would be found very efficacious and economical in the maintenance of earth roads to have the regular passage over them—one or more times, according to their importance—of a moderately heavy two-horse roller a few hours after the cessation of rains. About one roller to every twenty miles of ordinary road should be kept provided.

Referring to page 96: I should think it questionable whether the addition of hard pan to a clay road would be of use.

Referring to pages 99 and 100: It would be interesting to know the results of a combination of the first and last of the systems of rolling Macadam roads enumerated by Mr. North, that is, steam rolled and traffic made. I would suggest that the steam roller be first used without binding material, or with very little, to bring the road metal to a passable surface, and then open the road to traffic.

My experience coincides with that of Mr. North—that the hardest kind of stone, if of the proper size, will produce a firmer roadbed when traffic made, without softer binding material.

Referring to page 102: The reason why the Macadam in Basnat street, Liverpool, does not show the wearing qualities of a well puddled trap road I conceive to be not on account of the binding material—coal tar, pitch, &c.—but owing to imperfect consolidation due to hand rolling. I have no doubt that, the rolling being equal in all cases, a binding material of pitch as described would give better results than where cement, clay, or "hoggin" were used, as less water would reach the foundation, and the pitch would have more elasticity, giving somewhat without breaking or crushing.

Referring to page 103: M. Malo's picturesque description of the Macadamized streets of Paris will apply with equal force to London or New York.

As far as I have any experience, Macadam pavements are a failure for city streets, except in some isolated cases where the traffic is merely nominal, or where all other considerations except pleasure driving are out of the question.

Referring to page 110: One great reason for the unexpected success of Mott avenue was, in all probability, that the heavy rolling over the saturated fresh filling of earth of the road (some four or five feet in

depth) most thoroughly compacted it, hence, giving subsequently a very solid foundation for the Macadam.

Referring to pages 112 and 113: The transverse section of a pavement is most important. The general tendency is to give too much crown to the pavement. In streets where there are horse railroads this crowning has generally become excessive, the trackmen tending always to raise the track regardless of any established street grade, while the city employés who repair the pavements meekly assume that the track is at grade and pave flush with it, while at the same time the curb is maintained at grade or settles below it. It would seem proper that the authorities in charge of street roadways should, at the time a railroad is being built, determine a proper profile for it. This profile should be filed, and the railroad forced to conform to it.

Another fallacy is, that an excessive amount of crowning adds to the strength of the pavement on the principle of an arch, the paving blocks being the voussoirs and the curbstones the skewbacks. The absurdity of this illusion is readily apparent if we conceive of an arch of 30 to 60 feet span with a versed sine of one foot or less, skewbacks half a foot thick resting on compressible earth, and, more wonderful still, the voussoirs in contact only at the extrados. The greater the crown given to a pavement the less will the depressions resulting from poor paving be noticeable on account of holding water.

In an earth road the transverse slope should never be less than the longitudinal slope. This restriction I consider unimportant in a stone block pavement, as with this class of pavements there is no danger of ruts being formed by running water, while it is quite desirable to have the rainfall scour quite an extent of the pavement surface before reaching the gutters.

Gillespie says that the proper section of roadway surface should be formed by two planes inclined from the gutters upward towards the centre of the roadway, with their intersection rounded by a slight curve.

That this is correct I have tried to believe for a long time, but observation convinces me that it is not the best form. The arc of a circle is practically the best cross section for street pavements. If not from choice, at least from necessity, the bulk of travel is along the centre of the street, the portions on each side next the curb being occupied by vehicles standing. With a section of the arc of a circle the centre of the roadway is almost level. Another advantage is, that while the gutters are running full, the width of deep water is narrower than when the surface is an inclined plane.

Referring to page 114 : I fully agree with Mr. North as to the excellence of granite pavements in England. London, particularly, excels in the quality of its stone block pavements. I have seen nothing elsewhere equal to them for streets of heavy traffic. Their great superiority arises principally from their concrete foundations. It is surprising that similar foundations are not always used when the streets in the business portion of the city are relaid with stone blocks. The filling of the joints between the blocks with pitch I think would be a decided improvement upon the London plan of grouting.

Referring to page 115 : Wood pavements, as far I have any experience have been without exception, a failure. I can conceive that creosoting the blocks and filling the joints with bitumen would prevent decay, and thereby materially lengthen the life of this class of pavements, but, so far, nothing has been—and in all probability never will be—invented that will prevent wood, when subjected to an incessant impact and attrition of iron horseshoes and heavily loaded steel tires from acting as wood—that is quickly wearing down. The pits in the surface of wooden pavements have been proved by borings to be due much more to the actual wearing off of the wood than to settlement.

Referring to page 130 : My recollection of those sidewalks in Paris covered with asphaltic mastic ("bitumen" so called) is, that they are not very satisfactory. During July and August almost every footstep left an impression in the mastic, and in winter they were excessively muddy, and had generally sunk out of plane.

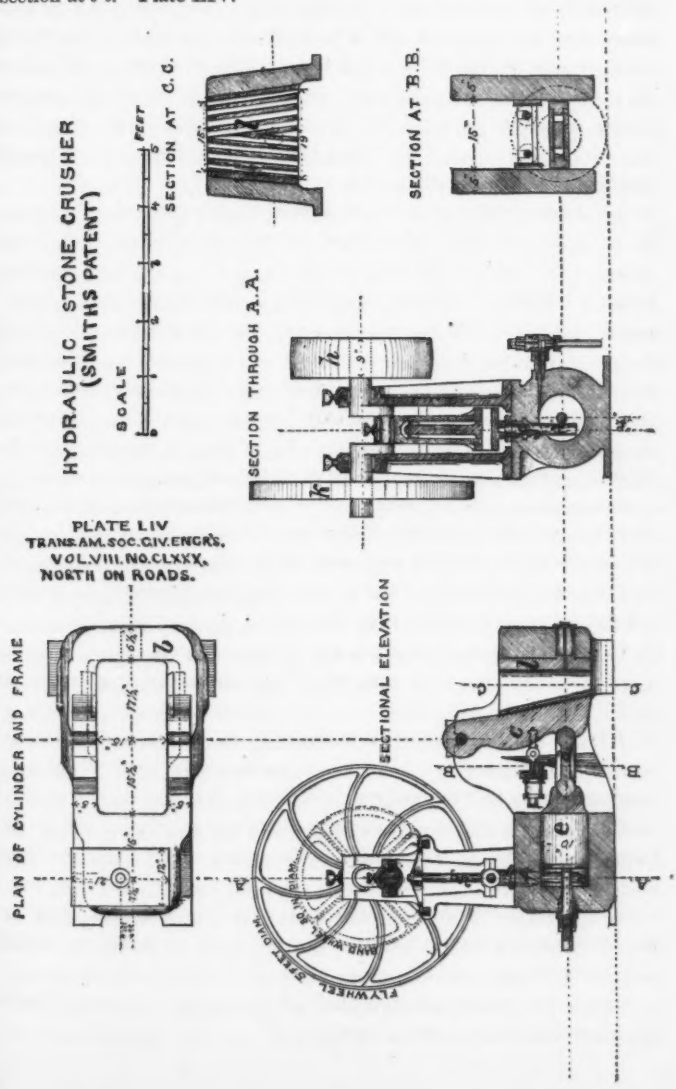
Have any experiments ever been made with the bituminous limestones found in this country to use them as paving material in the same manner as the regular asphalte ?

John Bogart.—Experiments were made some years ago in Chicago with a peculiar limestone, which it was thought might be utilized in a manner similar to the imported asphalte. The result was a good Macadam pavement, but apparently the impregnating matter had no advantageous effect—my recollection is that it was petroleum rather than bitumen, and that it did not exert any cohesive force.

C. C. Martin.—The Smith Hydraulic Stone Crusher as now manufactured possesses *two* peculiarities which render it superior in certain respects to former patents:

First.—The power is applied through an hydraulic cylinder, which has connected with it a safety-valve.

Second.—The opening through which the stones pass after being crushed is wider at the bottom than at the top, as shown by the cross-section at *c c*. Plate LIV.



These are the two essentially novel and good features of the machine; all of the rest are simply mechanical arrangements for transmitting the power from the engine to the machine, and may be arranged as here shown, or in any other way. In this machine *a* is the hydraulic cylinder, *b* is the frame, *c* is the movable jaw, *d* the toggle, *e* the hydraulic ram, *f* the plunger, *g* the connecting rod, *h* the band-wheel, *k* the fly-wheel, *l* the stationary jaw; the section *c c* is a front elevation of the stationary jaw. When the machine is to be made ready for use the ram, *e*, is drawn back so as to place the movable jaw, *c*, far enough from the fixed jaw, *l*, to permit stones of the largest required size to pass through between them; the plunger, *f*, is drawn up out of the hydraulic cylinder, *a*, and the cylinder is then filled with water or other liquid, and the safety-valve is weighted. The operation of the machine is as follows: Stones are thrown between the jaws and the engine started; as the crank-shaft revolves the plunger, *f*, is forced down into the liquid, and displacing a portion of it forces the ram forward, which, through the toggle, *d*, presses the movable jaw against the stone, which is crushed. The upward movement of the crank withdraws the plunger, and the ram is drawn back to its original position, and the jaw is again opened; thus, every revolution of the crank shaft produces one stroke of the jaw. The machine works well, running at two hundred to two hundred and fifty revolutions per minute, and will readily and regularly break seventy-five cubic yards of limestone in ten hours, to sizes varying from 1½ to 2½ inches largest dimensions

The advantage of the safety-valve is, that in case any stone which cannot be broken, a sledge hammer dropped from the hands of a careless workman, or any other unyielding body, gets between the jaws, the only effect is to force open the safety-valve and permit the escape of a portion of the liquid from the cylinder, thus stopping the motion of the jaw without stopping or changing the motion of the fly-wheel. The liquid thus discharged is received in a small tank, and the continued motion of the machine pumps it back into the cylinder, and the crushing goes on. If the obstruction still continues, the safety-valve is again opened. The result of this safety attachment is that the machine is never broken.

The advantages of widening the jaw at the bottom are two-fold, as will appear from a consideration of the operation of the stone in the crusher. The broken stones occupy more space than the unbroken, and the smaller the pieces the more space do they occupy. The stone entering at the top of the jaw is broken, and each successive stroke crushes it

more, and in the old style of jaw the stone became clogged and many pieces were ground to powder before they could escape, thus wearing out the jaws and cheek pieces, and consuming unnecessarily a large amount of power. The widened jaws permit the stones to escape as soon as they are broken, thus leaving them of more uniform size, making less dust, and breaking them with the least possible expenditure of power.

EDWARD P. NORTH.—Regarding objections made to certain clauses in the paper under discussion, it may be said that the roller with unequal sized disks was not advised for maintenance, but unless it was so guided that the larger disks always followed the same tracks its use would cause less tendency to longitudinal ruts in the road than the ordinary traffic.

The advisability of surfacing a clay road with hard pan must depend greatly on the character of the hard pan—a clay hard pan might be objectionable.

Messrs. Spielman & Brush's practice, as detailed on p. 333, is undoubtedly sound under the circumstances, viz.: an absence of water for compacting and puddling, but a better road, with less tendency to internal wear, would have been formed by a steam roller, if sufficient water could have been procured.

Lavoinne seems to have misunderstood the effect of the screenings, *i. e.*, small fragments of stone from the breakers. The coarser of these are applied only when compacting has proceeded so far that the stones have a tendency to roll over one another and round their angles; these screenings bind the stone and prevent to a great extent further wear. About 33 per cent. of screenings are worked into the metal and are used in puddling. Probably about 25 per cent. of this is coarse screenings in the interstices between the stones, the rest being fine screenings and that used in puddling.

Law & Clarke, p. 145, give 10 or 11 cubic feet interspace per yard—40 per cent in compacted stone. In Paris, about 24 per cent of sand is used in binding, and, as above stated, 33 per cent. of screenings are used here.

It was not the intention to argue for poorly constructed wooden pavements, but rather to show the practice where wood pavements are successful, with the hope that it might be followed in this country. The fact that wood pavements as usually constructed here and never repaired have proved failures, cannot be denied, but that a well made and intelligently maintained wood pavement would be a failure is doubted.

The following memorandum from Cleveland confirms this view: "In the year 1873, 5070 square yards of creosoted wooden pavement were laid in Franklin street, Cleveland. The pine blocks were creosoted with about 4 lbs. of oil per cubic foot. Since that time no money has been expended in maintenance, and the pavement is in excellent order.

At the same time, and in the same street, an equal area was laid with blocks prepared by the "Thilmany" process; of this, 1400 square yards have been relaid by the city."

It is unfortunate that the asphalte pavements in Washington were so poorly laid.

I street has such an excessive crown, that it is only in the center of the wheelway that the street is sufficiently flat for ease or comfort in driving.

On Pennsylvania avenue the transverse profile is good, but the heated powder was apparently laid on damp concrete, and the surface is badly cracked in consequence, and has been extensively repaired, though it was laid in the fall of 1877, and it is doubtful if it wears more than five years in all.

In Paris, with a much heavier traffic, asphalte lasts 15 years.

The bituminous mastic pavements described by Mr. McComb present very fine surfaces, and, if they wear as well as now hoped, will have all the advantages of compressed asphalte, except durability, at reduced cost, and their use may be advisable in streets of light traffic.

The present practice is to make the wearing surfaces harder than has been usual, it having been held that *all* mastic pavements, subjected to street traffic, should be made so soft as to dent in summer, to prevent their breaking up in winter.

The weak point of bituminous mastics seems to lie in the expense necessary to free the Trinidad bitumen from clay, and the difficulty of getting sand that is free from clay, and fine enough to absorb sufficient bitumen for cohesion in cold weather, without an excess in hot weather. Loam or loamy sand was used at first to enable the mixture to carry sufficient bitumen for wear, but the rapid rotting in the gutters, and at other points where water lies, has led to the use of 15 to 16 per cent. of limestone, ground to pass through a sieve with 26 meshes to the inch, which probably will not be so detrimental to the mastic as clay.

In reply to a question as to the amount of clay allowed in mastic work in Europe, M. Leon Malo writes: "In principle, no clay at all

ought to be in mastic; the asphalte rock, being quite pure limestone, is desired to be mixed with quite pure bitumen. But, in reality, the bitumen of Trinidad having been generally adopted in works by want of pure mineral bitumen, and as it is impossible to quite deprive that bitumen of its clay, it is admitted that the clay brought into the asphalte works by the Trinidad bitumen can be accepted; that is to say, from 2 to 3 per cent. of clay in the mastic. For the compressed asphalte, to which no bitumen is added, not one quantity of clay is allowed."

Regarding the asphaltic mastic sidewalks of Paris, it should be noted that there is always a temptation on the part of the mastic workers to use too much bitumen, as the larger the percentage the more easily the mastic is worked; and, unless it is kept very low, the pavement will dent in hot weather. The mud must have been brought on from the wheelways, as, according to Chabrier, the mastic sidewalks under the arcades of the Rue de Rivoli, Paris, wore about half an inch in 13 years—too small a wear to produce much mud.

The necessity for better pavements than those offered by the prevalent granite blocks, will justify the insertion of a translation from M. Leon Malo's "*Note sur L'Etat Actuel de L'Industrie de L'Asphalte, Paris*, 1879."

The experiment of compressed asphalte for carriageways has now been made. It has shown its defects and its advantages; we do not hesitate to say that its advantages far exceed its defects.

We do not now speak of its noiselessness nor of its precious property of creating neither dust nor mud; of its agreeable aspect to the eye, which is a quality not to be neglected in the *ensemble* of the embellishment of a city; we have shown the importance of these in our first work. We insist only on its action upon the public health; a point which we did not sufficiently emphasize.

The asphalte, placed over the soil, like a layer of caoutchouc, absolutely intercepts any communication between the soil and the atmosphere; it does not allow rain water, which runs rapidly into the sewers, to penetrate; and thanks to its water-repelling ("*hydrofuge*") character, the carriageways dry as soon as the rain has ceased.

A stone pavement, on the contrary, permits a constant communication between the soil and air through its joints. All the impurities of the surface, dissolved by the surface waters, are by them carried into the earth; then, when the sun strikes it, these impure waters are evaporated,

returning miasma, bred below the pavement, into the air; it is an evil which has been long recognized and uncontested, but against which no remedy is known.

The system of joining pavements with asphaltic mastic might, perhaps, obviate it, but it is very costly, and renders the carriageway extremely hard for vehicles. Compressed asphalte seems to have solved the problem; and we are compelled to think that of all the services which it can render, this is the most efficacious and the most precious. To be sure, the influence of deleterious miasmas radiated from the different systems of pavements with open joints, cannot be analysed in a precise manner; it is judged rather by induction than by a direct observation which can be put in figures; but it is not the less evident and not the less to be dreaded.

M. Malo also gives the following tabulated results of analysis made in the laboratory de L'Ecole des Pouts et Chaussées on different asphaltes:

	Val de Travers.	Seyssel.	Lobsan.	Sicilian.	Maestu.	Forens.
Water and matter volatile at 212° F[1]	0.50	1.90	3.40	0.80	0.40	0.25
Bitumen	10.10	8.00	11.90[2]	8.85	8.80	2.25
Carbonate of lime	87.95	89.55	69.00	87.50	9.15	97.00
Silicious sand	"	"	3.05	0.60	57.40	"
Aluminum and peroxide of iron	0.25	0.15	5.70[3]	0.90	4.35	0.15
Sulphur	"	"	5.00	"	"	"
Carbonate of magnesia	0.30	0.10	0.30	0.95	8.10	0.20
Different minerals insoluble in acids	0.45	0.10	"	"	11.35	0.05
Loss	0.45	0.20	1.65	0.40	0.45	0.10
	100.00	100.00	100.00	100.00	100.00	100.00

NOTES: 1. The water given above depends on the dryness of the sample at the time of analysis; the figures not being of importance in the results.

2. This quantity appeared to contain a certain proportion of oil, which was mixed with the bitumen and was not exactly determined.

3. This comprises 4.45 of iron, combined with sulphur.

M. Durand-Claye, Director of the laboratory, speaking of the Lobsan, says: "It contains about 9½ per cent. of pyrites, which may become the cause of failure in employing this material. The heat to which it is submitted may cause it to lose half of its sulphur, and be transformed into protosulphate of iron, an oxydizable material, which by exposure to the air is transformed into a soluble sulphate of iron; disintegration might result from this a short time after putting it in place."

Mr. H. F. Starr, of the Columbia College School of Mines, kindly made an analysis of some Limmer asphalte, which gave the following result:

Bitumen	8.26
Clay	4.98
Carbonate of lime	56.54
Carbonate of magnesia	27.01
Sesqui oxide of iron	3.21
	100.00

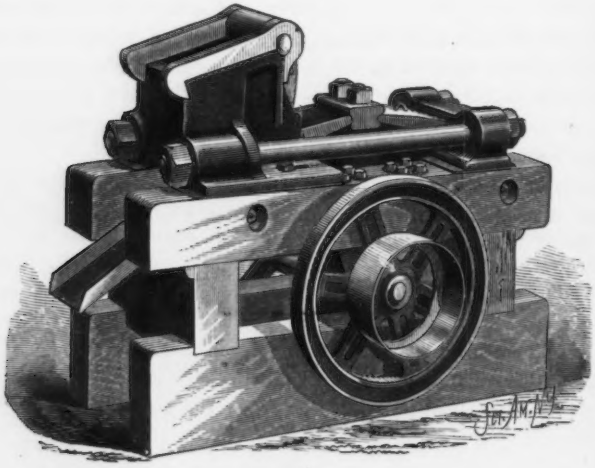
This is the only analysis I have seen of an asphalte that will not compress, and the only one, excepting the Maestu, in which there is over 1 per cent. of carbonate of magnesia.

M. Malo gives analyses of seven different cargoes of crude Trinidad bitumen. In each case the samples were thoroughly dried, losing from 32 to 38 per cent., after which the average of the analysis was bitumen 51½, and clay 48½ per cent. The greatest percentage of bitumen in any sample was 57.55, and the least 45.

In addition to the description of the hydraulic crusher furnished by Mr. Martin, a mention of the new Blake crusher may be of interest. See figure.

In it the old cast-iron frame is replaced by steel rods and a wooden frame, so cushioned that the fly-wheel, in case of abnormal resistance, can make a part of a revolution. The pitman, which is above the driving-axle, can be lengthened or shortened, so as to increase or diminish

the stroke of the jaws, and the length of the toggles has been increased. It is probable that these changes will reduce the expense of stone-breaking by diminishing the breakage account, which, particularly with trap rock, is a serious item.



Mr. J. L. Gillespie, C.E., gives me the following as the cost of breaking 15 150 c. yards of limestone during 1874–5–6–7, for the concrete used in the preservation of the Falls of St. Anthony. The machine, an 8″×16″, old pattern Blake, was run by water power, for which there was no charge.

The cost and quantities were as follows, the stone being delivered at the breaker:

1874–5	3 452 c. yds. at	41.	cents.
1875–6	8 284 "	31.8	"
1876–7	3 414 "	18.	"

1 c. yd. of stone produced about 2 c. yds. of broken stone, the void spaces in which amounted to $50\frac{5}{7}$ per cent. The breakages were confined to some rubber springs, 1 back block, and 2 sets of jaws and cheeks.

The cost of breaking trap on the Palisades is given as follows, the stone being sledged, to go into the jaws readily.

Two crushers deliver 35 c. yds, of 2″ stone per day, when working well; 15 per cent. of the time is lost by breakdowns.

COST.

1 Engineman and fireman, at $2 50	..	$2 50	
2 Laborers, feeding..... 1 25	..	2 50	
2 " screening..... 1 25	..	2 50	
		——	$7 50
Coal, 1 ton.....			3 50
Oil and waste.....			1 00
Breakages.....			5 00
			$17 00

or, say 57 cents per c. yd.

On Snake Island three crushers were arranged in a row, and the broken stone was carried by an endless belt to the revolving screen, whence it fell into the bins, so that no screeners were employed. The engine had one cylinder, 8″×24″, and was running with 80 pounds of steam. The product was said to be 180 c. yds. per day when there was no breakdown.

COST.

1 Engineman and fireman, at $2 50	..	$2 50	
3 Laborers, feeding..... 1 25	..	3 75	
		——	$6 25
2½ tons of coal, at $3 50.....			8 75
Oil, &c.			2 00
Breakages.....			15 00
			$32 00

Allowing for the 15 per cent. lost by breakdowns, the cost would be about 21 cents per c. yd.

At another place on the Hudson, 2 crushers, set face to face, 9″×15″ jaws, could deliver at the rate of 120 c. yds. per day, when no trouble occurred, but 100 c. yds. was a fair average.

COST.

Engineman and fireman	$2 50	
3 Feeders	3 75	
2 Screeners	2 50	
		$8 75
1½ tons coal, at $4		6 00
Oil, &c		2 25
Repairs		10 00
		$27 00

or 27 cents per c. yd.

NOTE.—A detailed statement of the cost, in time, of breaking stone is given in the Memoir on the Construction of a Masonry Dam, by J. J. R. Croes. Transactions of this Society, No. CIII., Vol. VIII., page 356 (February, 1875).—[EDITOR.]

APPENDIX NO. 6.

SPECIFICATIONS FOR THILMANISING LUMBER FOR MINNEHAHA BRIDGE.

C. Shaler Smith, Consulting Engineer.

Steaming.

After being placed in the cylinder, the lumber shall be exposed to a steam bath which shall be continued for 90 minutes, for sticks under 10 feet in length, and nine minutes additional for each additional foot of length of the sticks treated, or until an analysis shows that the albumen of the sap has been completely coagulated, and the watery part thoroughly diluted or vaporized so as to flow freely.

During this process, the steam must not at any time exceed 240° F. in temperature, or 5 pounds in pressure per square inch in the receiving cylinder.

Vacuum.

On the completion of the steaming,—the steam shall be shut off, and a vacuum of not less than eleven pounds, produced in the receiving cylinder by the use of a vacuum pump,—which vacuum shall be maintained for 40 minutes, for sticks less than ten feet in length, and six minutes additional for each additional foot, or until moisture has ceased to flow from the wood.

First Injection.

A solution of sulphate of zinc, made by dissolving one pound of salt in fifty pounds of water, and having a specific gravity of 1.012, shall then be let into the cylinder from its lowest point, while the vacuum is still being maintained by the vacuum pump,—the supply pipe of which shall issue from the highest point of the cylinder. When the cylinder is filled with the solution, an injection pump shall be used to attain a pressure of 100 pounds per square inch, which pressure shall be maintained until the solution has penetrated every part of the wood under treatment. The time requisite for this shall be fixed by the Inspector after an experimental test or tests to determine it.

Second Injection.

After the zinc solution has been drawn off from the cylinder, a light vacuum of four pounds shall be produced by use of the vacuum pump, and a solution of chloride of barium, made by dissolving one pound of the salt in forty-five pounds of water, and having a specific gravity of 1.021, shall be let in as prescribed in the case of the first injection, during the maintainance of the vacuum, and then a subsequent pressure of 100 pounds per square inch shall be produced, and continued until the penetration of the wood by the barium

solution is complete, and all the pores of the wood are fully charged with the resultant salts of chloride of zinc and sulphate of barium. No uncombined zinc or free sulphuric or muriatic acids, shall be left in the wood after this last process, and the time required to effect these results shall be fixed by the Inspector after experimental tests covering all the varieties of lumber and length of sticks included in the contract, to which these specifications shall be attached.

General Specifications.

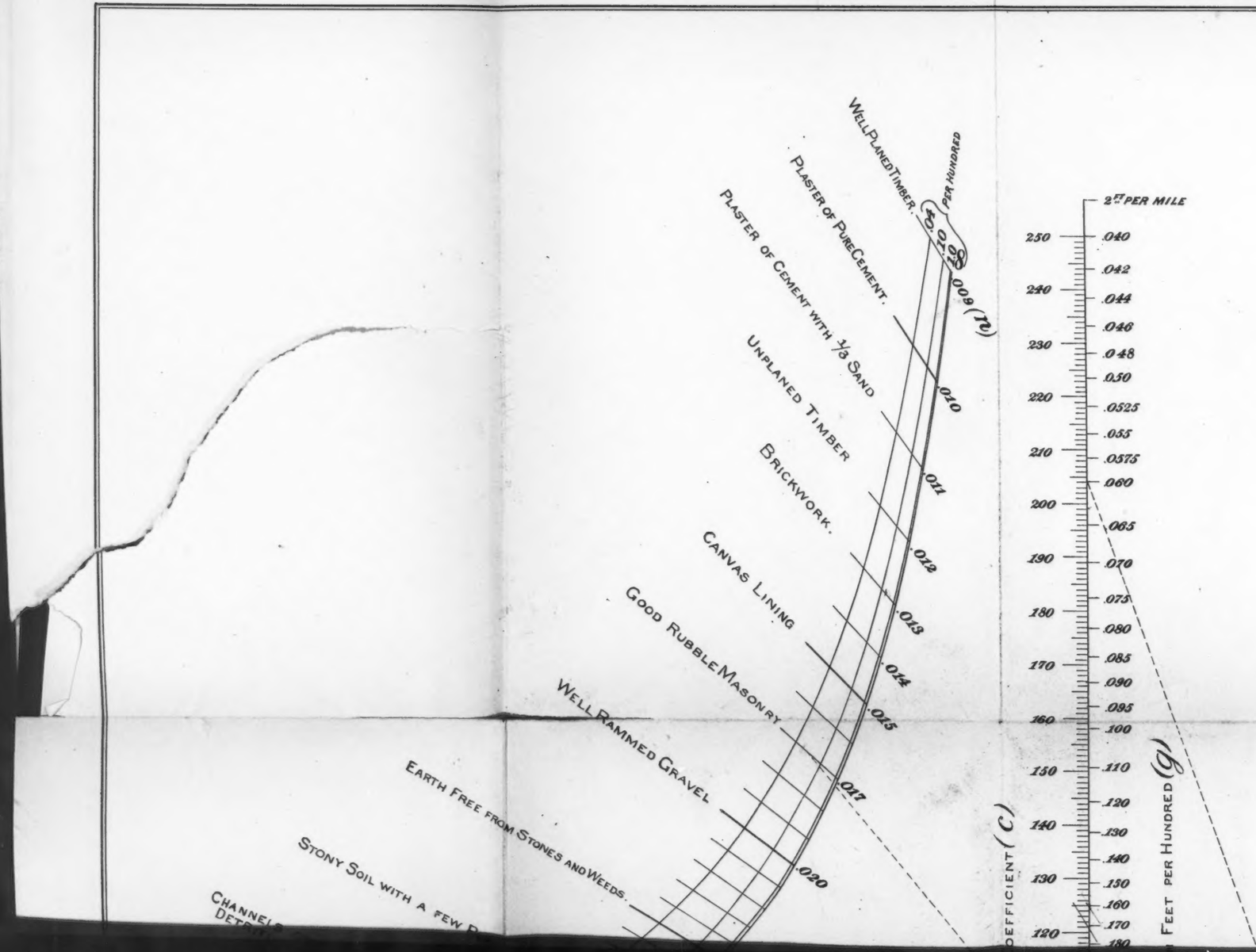
Where sticks of various lengths are contained in the same charge, the length of the longest stick shall fix the time required for the several processes.

Where different varieties of wood are included in the same charge, the time for each process shall be based upon that wood which requires the longest time in treatment.

Where wood is burnt by long continued steaming, or by superheated steam, it shall be rejected entirely, and shall be replaced by the Wood Preserving Company, at its own expense, if the deterioration is due to a violation of these specifications. Where sticks are found to be imperfectly de-albumenized, or insufficiently injected, they shall be treated a second time, or until they are completely charged as above specified.

After each solution is drawn off into its tank it shall be tested, and its percentage of the salt brought up to the standard herein specified before it is used again.

Should either solution become objectionably impure from frequent use, it shall be run out of the tank and a fresh solution shall be made.



Flow of Water

D

(Af

FOR OBTAINING THE RELATIO

MEAN

KUTTER'S

MEAN HYDR

ROUGHNESS OF

SLOPE OF WATER SURF

IN KUTTER'S FORMULA $v =$

ARRANGED WITH SPECIAL

RU

PLATE I.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. No. 1.
HERING ON FLOW OF WATER.

FLOW OF WATER IN SMALL CHANNELS

Diagram,

(AFTER KUTTER)

FOR OBTAINING THE RELATIONS IN ENGLISH MEASURE BETWEEN

MEAN VELOCITY (v)

KUTTER'S COEFFICIENTS (C)

MEAN HYDRAULIC RADIUS (R)

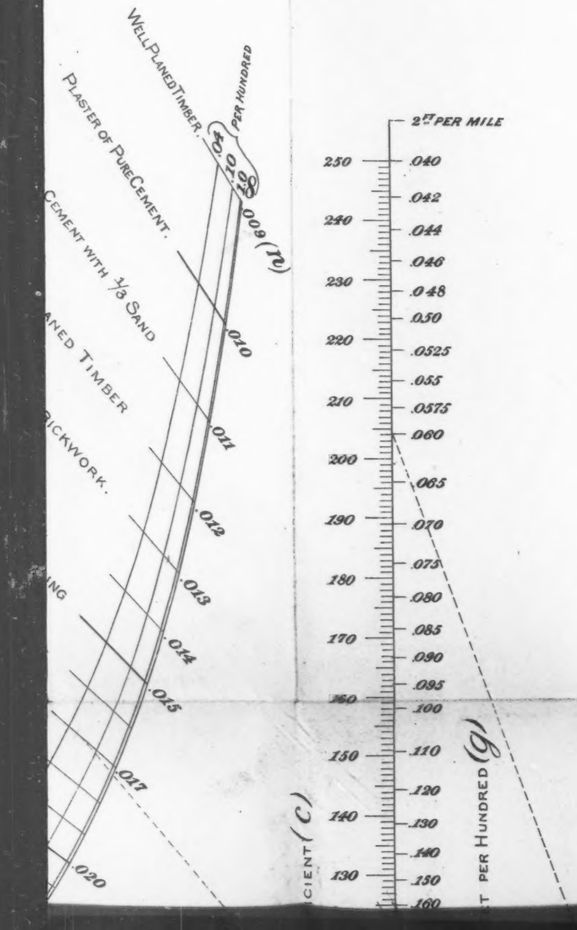
ROUGHNESS OF WETTED PERIMETER (n)

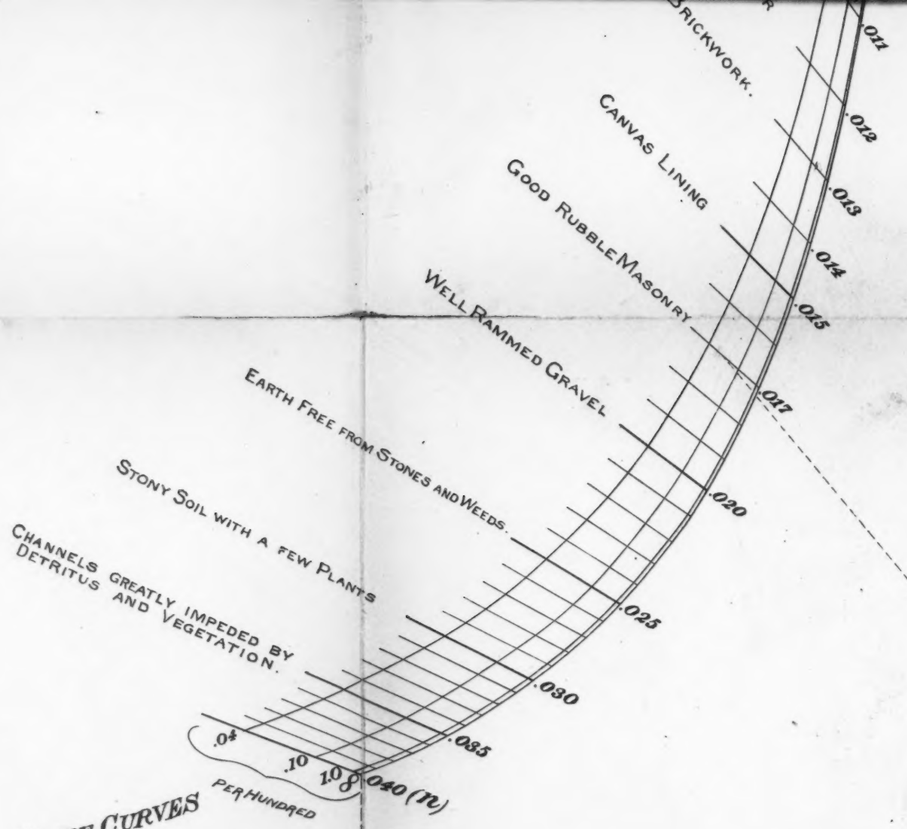
SLOPE OF WATER SURFACE (s) OR GRADE PER HUNDRED (g)

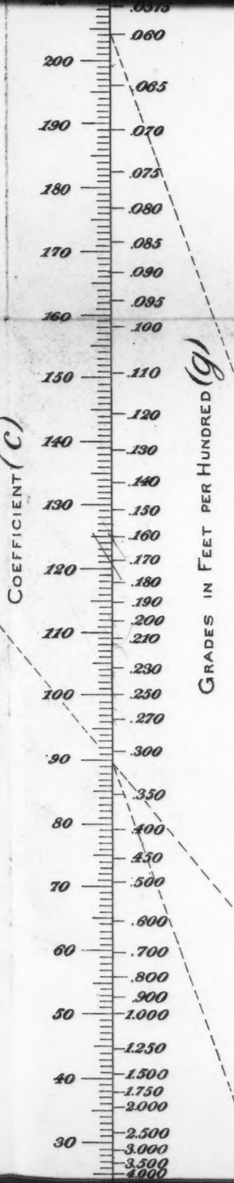
IN KUTTER'S FORMULA $$v = \left\{ \frac{41.66 + \frac{1.8113}{n} + \frac{.002807}{s}}{1 + \left(41.66 + \frac{.002807}{s}\right)\frac{n}{\sqrt{R}}} \right\} \sqrt{Rs} = C\sqrt{Rs}$$

ARRANGED WITH SPECIAL REFERENCE TO SEWER CALCULATIONS

BY







Mean Velo

Kutter's Coef

Mean Hydrauli

Roughness of Wet

Slope of Water Surface (

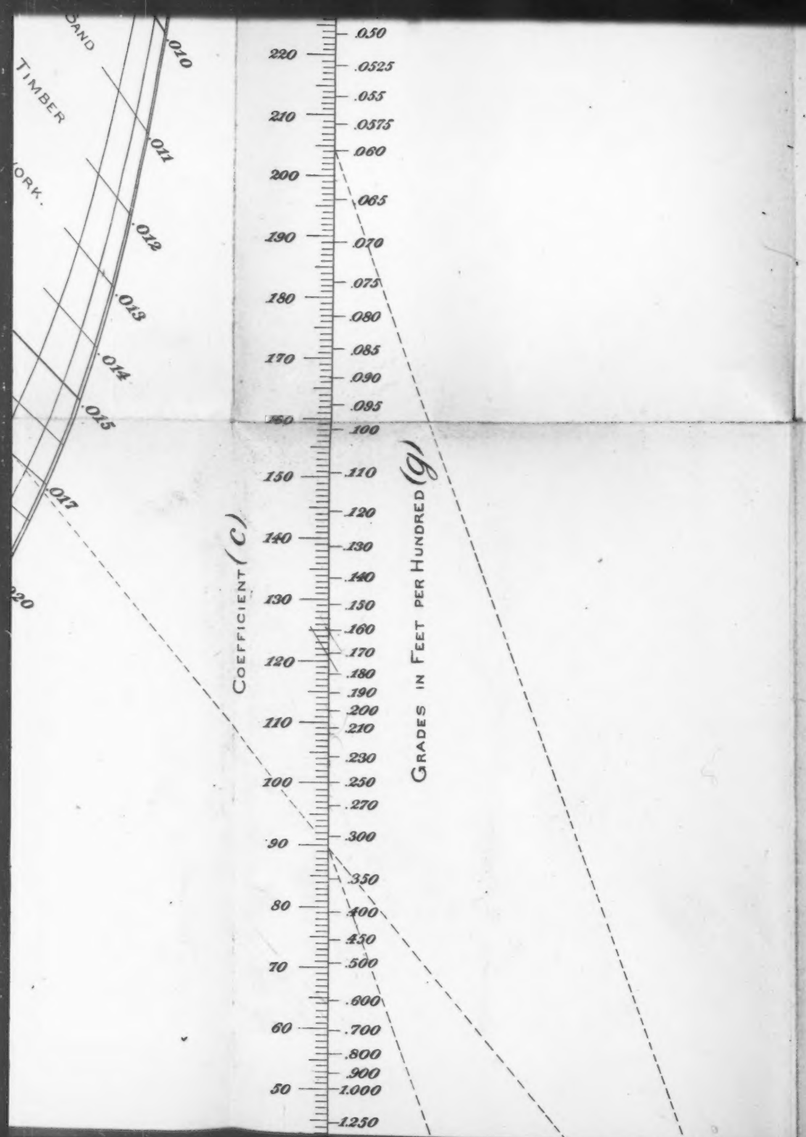
In Kutter's Formula $v = \left\{ \frac{41.6}{1+\left(\right.} \right.$

Arranged with special refe

Rudolp

Values of R for Semicircular Channels running Full with Diameters of

1ft 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20



(AFTER KUTTER)

FOR OBTAINING THE RELATIONS IN ENGLISH MEASURE BETWEEN

MEAN VELOCITY (v)

KUTTER'S COEFFICIENTS (C)

MEAN HYDRAULIC RADIUS (R)

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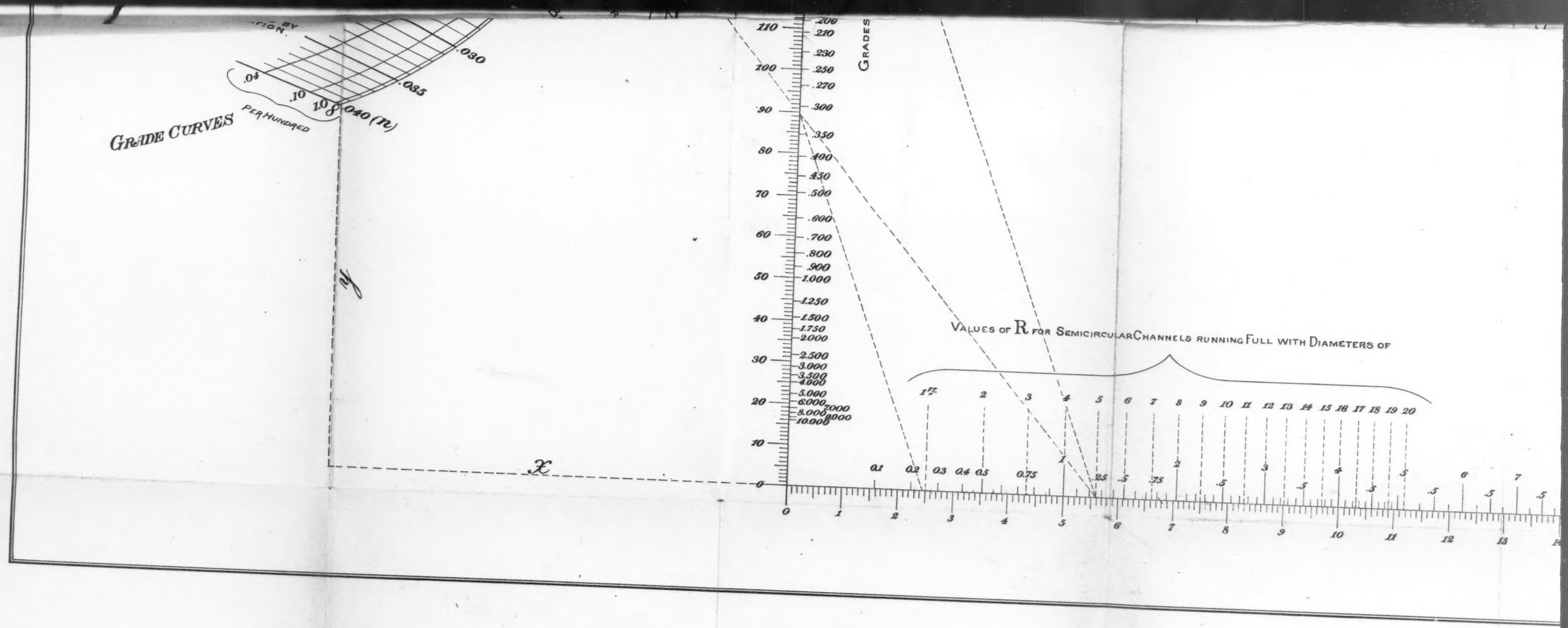
ARRANGED WITH SPECIAL REFERENCE TO SEWER CALCULATIONS

BY

RUDOLPH HERING.


GRADE CURVES
PER HUNDRED
.04
.10
1.0
.030
.035
.040 (n)
GRADES
110
100
90
80
70
60
50
40
30
20
10
0
.200
.210
.230
.250
.270
.300
.350
.400
.450
.500
.600
.700
.800
.900
1.000
1.250
1.500
1.750
2.000
2.500
3.000
3.500
4.000
5.000
6.000
7.000
8.000
9.000
10.000
x
y
VALUES OF R FOR SEMICIRCULAR CHANNELS RUNNING FULL WITH DIAMETERS OF
1 ft.
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0.1
0.2
0.3
0.4
0.5
0.75
1
.25
.5
.75
2
.5
3
.5
4
.5
5
.5
6
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7
.5
0
1
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11
12
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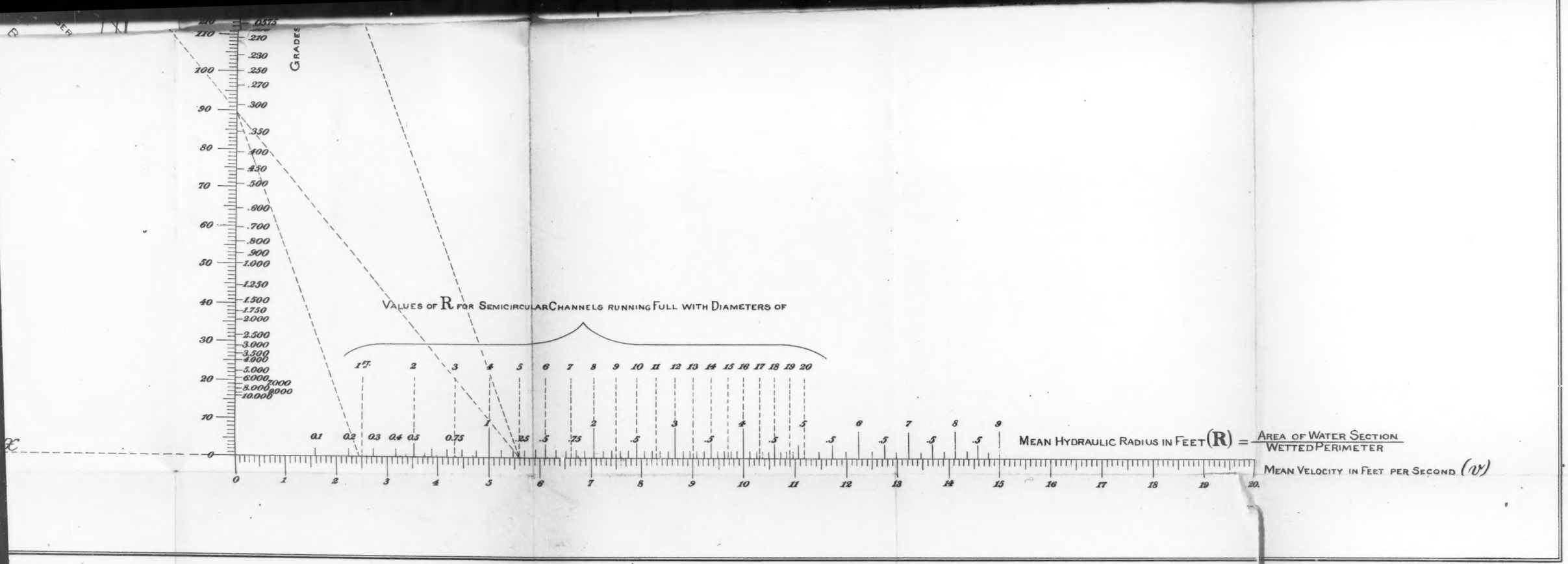
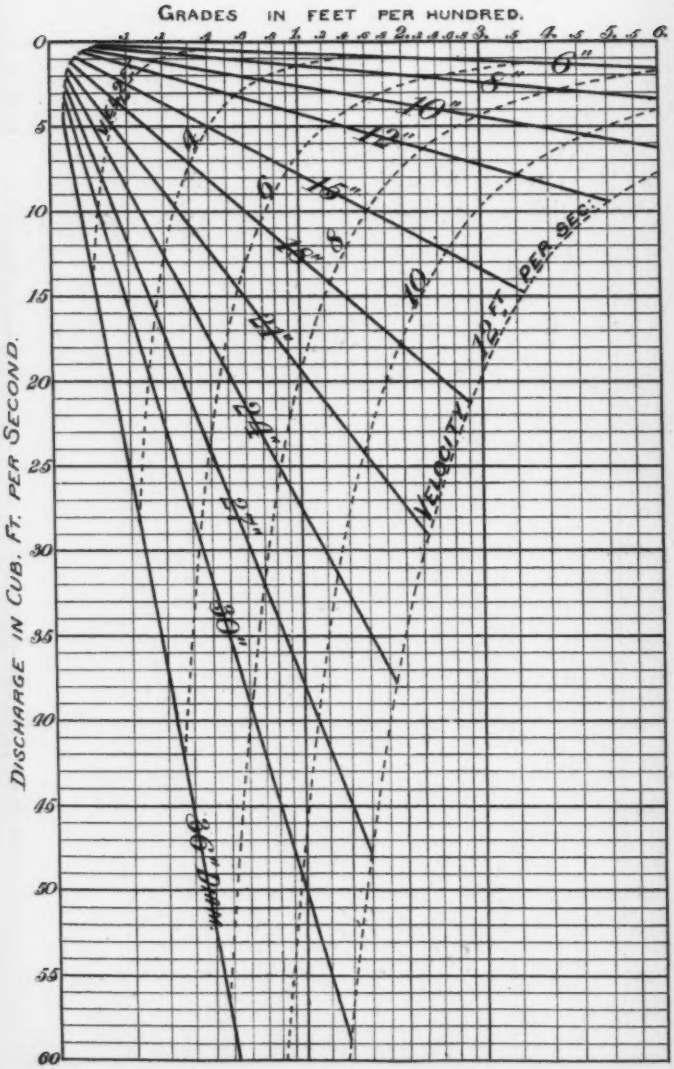

GRADES
VALUES OF R FOR SEMICIRCULAR CHANNELS RUNNING FULL WITH DIAMETERS OF
MEAN HYDRAULIC RADIUS IN FEET (R) = AREA OF WATER SECTION / WETTED PERIMETER
MEAN VELOCITY IN FEET PER SECOND (v)

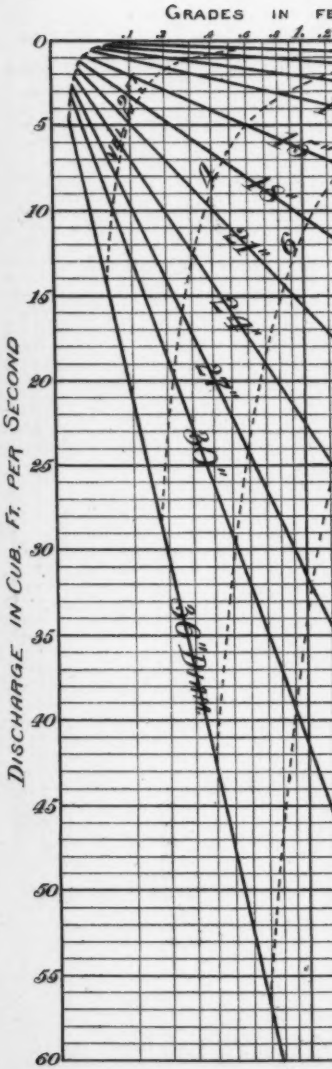
A.M. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS)

PIPE SEWERS

$n = .011$



$n =$



S RUNNING FULL.

n=.013

IN FEET PER HUNDRED.

.1 .2 .4 .6 .8 1. 2 2.4 2.6 2.8 3. 3.5 4. 4.5 5. 5.5 6.

6" 8" 10" 12" 15" 18" 24" 30" 36" 42" 48" 54" 60" 72" 84" 96" 108" 120"

VELOCITY 12 FT. PER SEC.

n=.015

GRADES IN FEET PER HUNDRED.

.1 .2 .4 .6 .8 1. 2 2.4 2.6 2.8 3. 3.5 4. 4.5 5. 5.5 6.

DISCHARGE IN CUB. FT. PER SECOND.

0 5 10 15 20 25 30 35 40 45 50 55 60

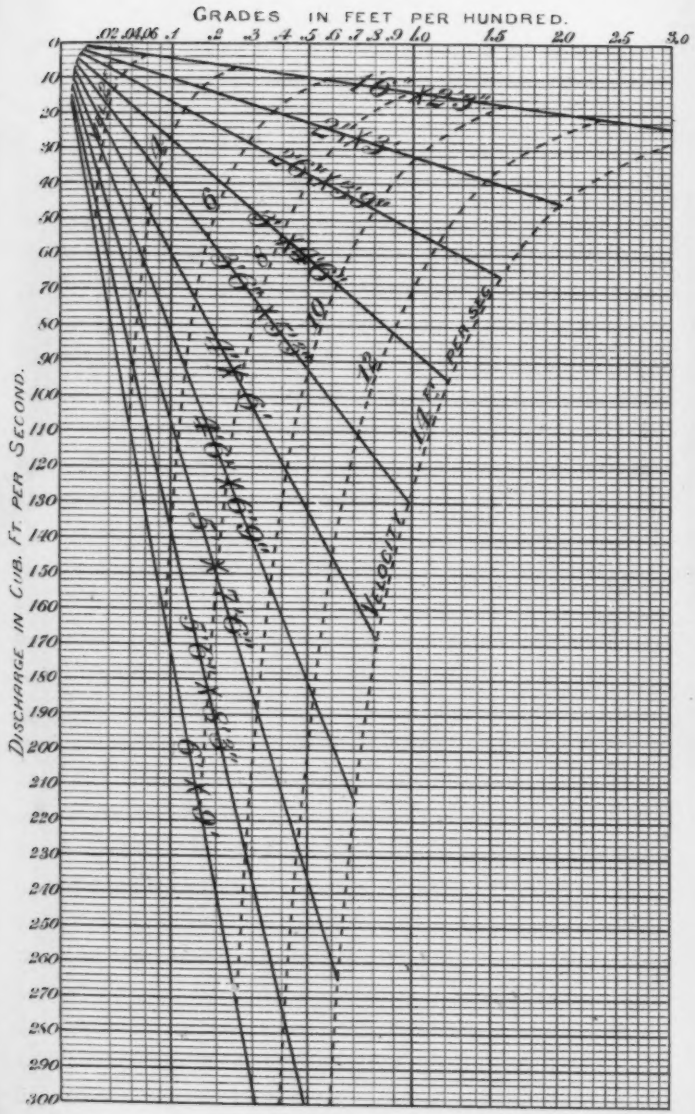
6" 8" 10" 12" 15" 18" 24" 30" 36" 42" 48" 54" 60" 72" 84" 96" 108" 120"

VELOCITY 12 FT. PER SEC.

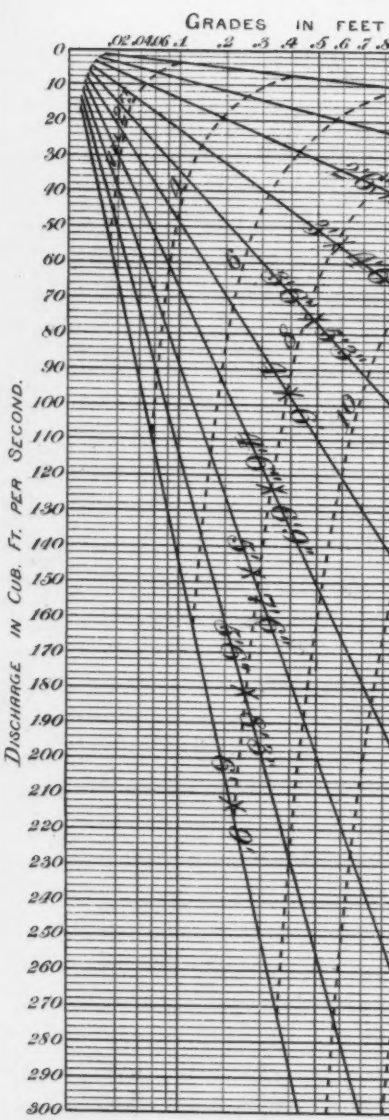
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

EGG-SHAPED SEWE

n=.011

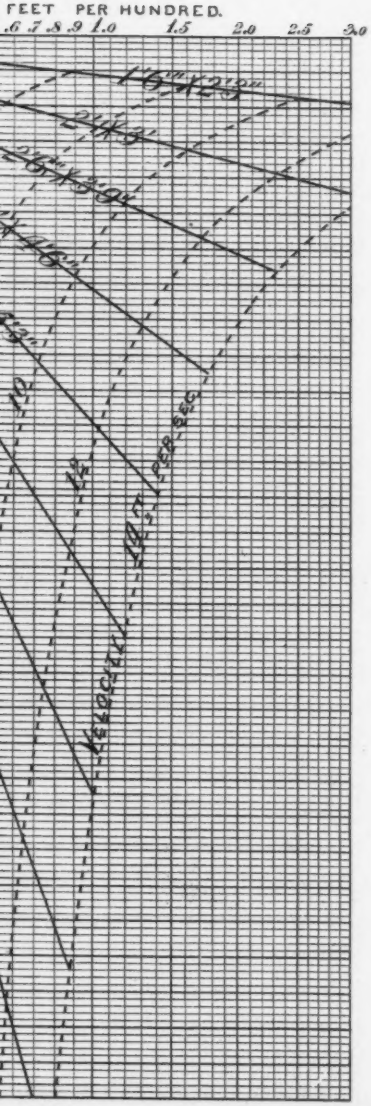


n=.0

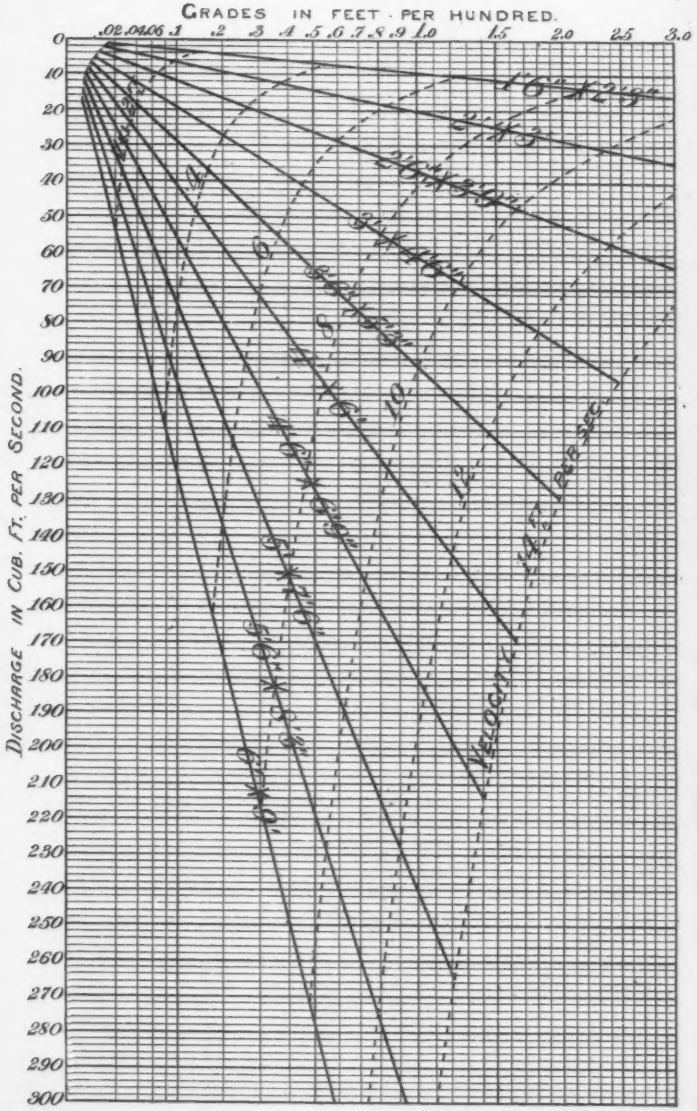


VERS RUNNING $\frac{2}{3}$ FULL.

$n = .013$



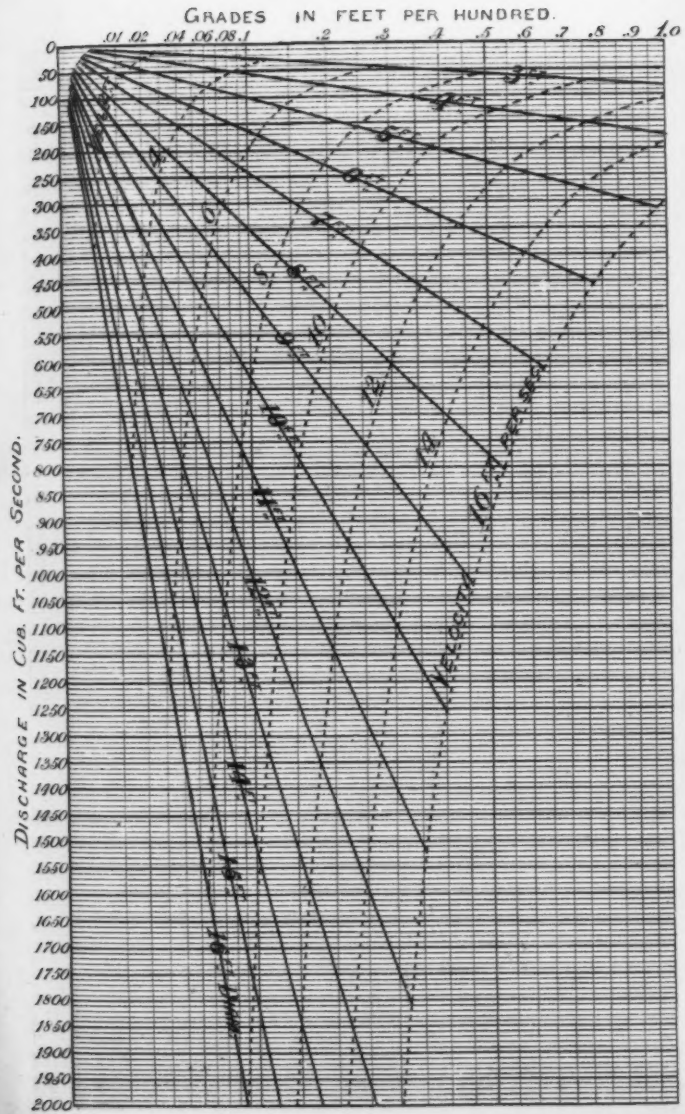
$n = .015$



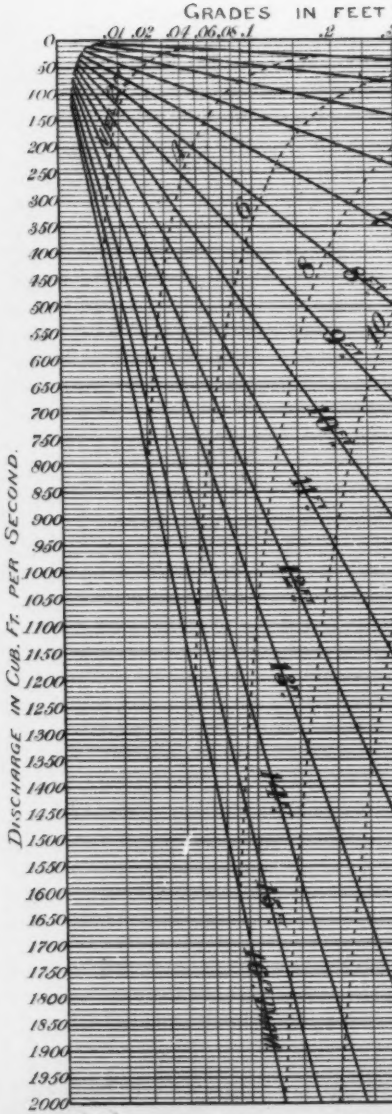
AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

CIRCULAR SEWERS

n=.011



n=.0



RS RUNNING FULL.

n=.013

FEET PER HUNDRED.

.2 .3 .4 .5 .6 .7 .8 .9 1.0

n=.015

GRADES IN FEET PER HUNDRED.

.01 .02 .04 .06 .08 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

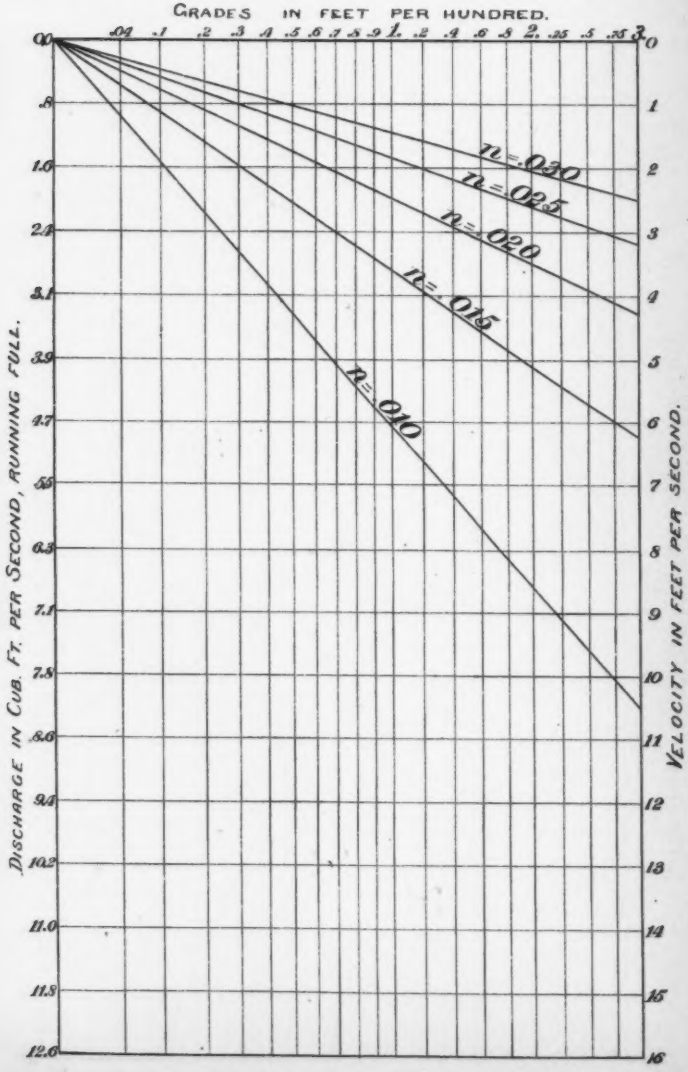
DISCHARGE IN CUB. FT. PER SECOND.

0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000

AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)

DIAGRAM SHOWING INF

CIRCULAR SEWER 1FT DIAM.



CIRCULAR S

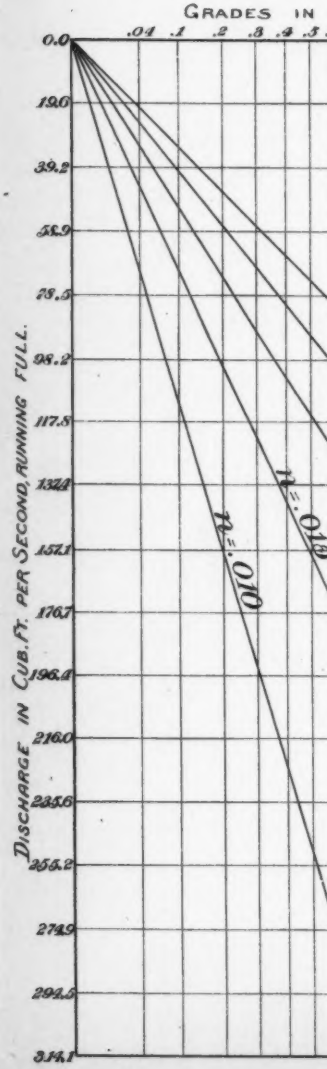
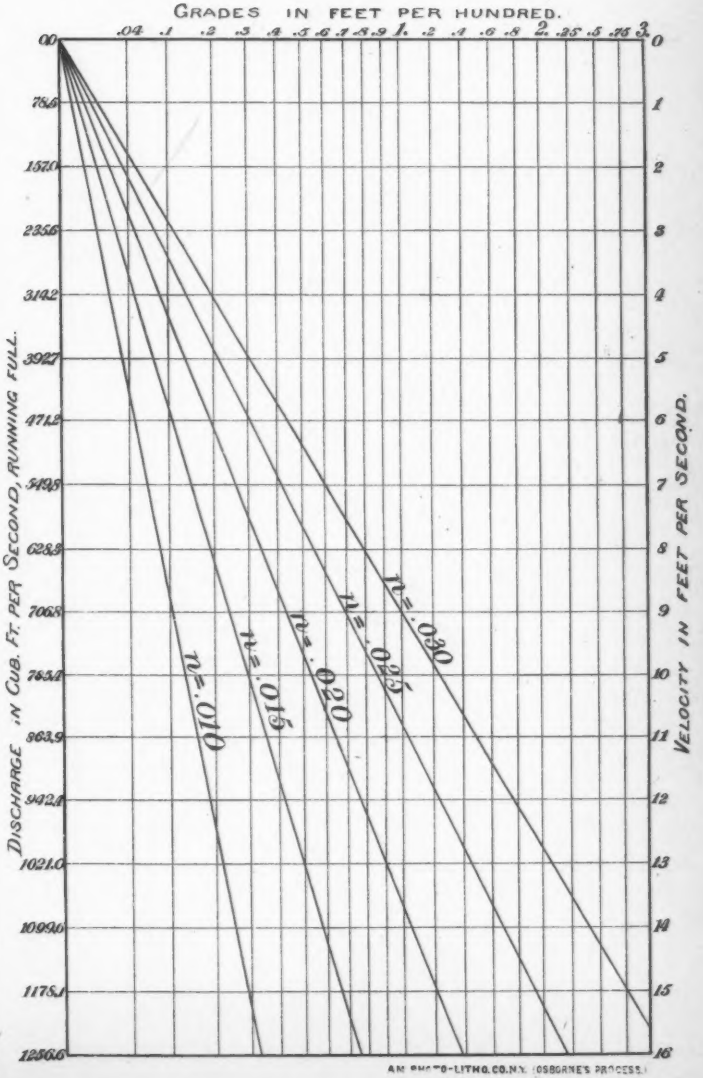


PLATE V.
TRANS. AM. SOC. CIV. ENGR'S.
VOL. VIII. No. CLXXV.
HERING ON FLOW OF WATER.

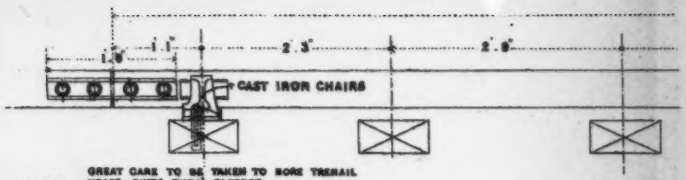
NFLUENCE OF ROUGHNESS.

IR SEWER 5FT. DIAM.

CIRCULAR SEWER 10FT. DIAM.



AM. PHOTO-LITHO. CO. N.Y. (OSBORNE'S PROCESS.)



NOTE.

GREAT CARE TO BE TAKEN TO BORE TREnail HOLES QUITE THRO' SLEEPER.

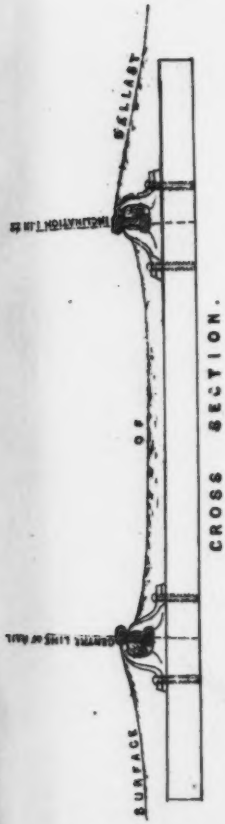
TREnails, SPIKE, AND THREAD OF FISH BOLTS TO BE DIPPED IN TAR BEFORE USING.

THE KEYS TO BE DRIVEN IN THE SAME DIRECTION.

AS THE TRAINS TRAVEL WHENEVER PRACTICABLE.

NUTS TO FISH PLATE BOLTS TO BE ON OUTSIDE OF LINE.

GREAT EASTERN RAILWAY



CROSS SECTION.

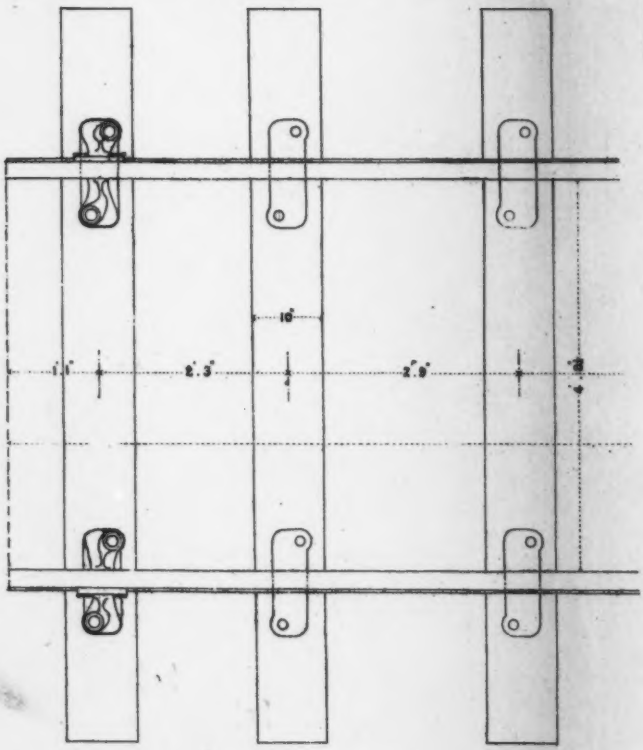
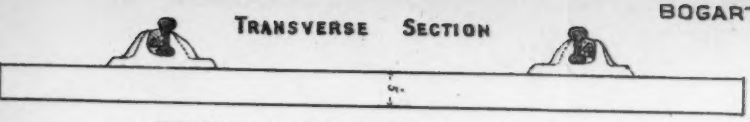
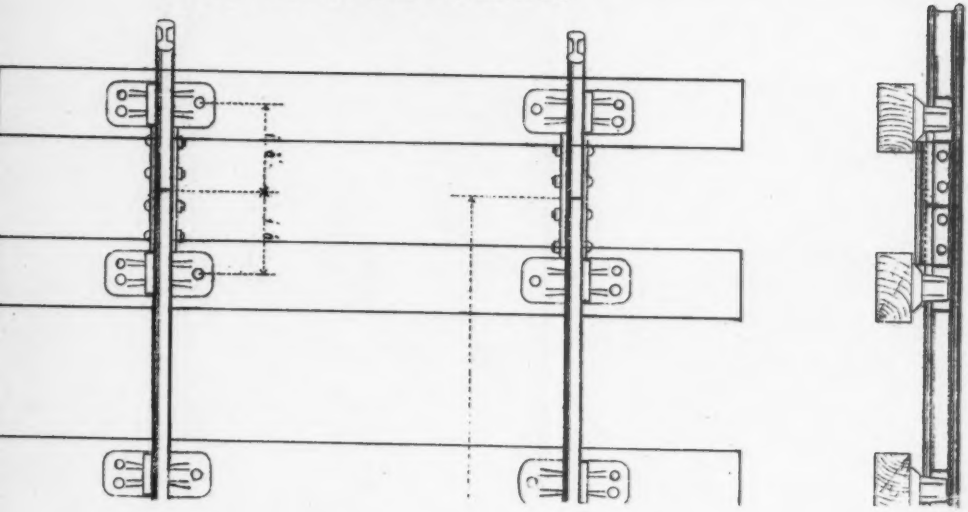


PLATE VI
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII No. CLXXVI
BOGART ON PERMANENT WAY

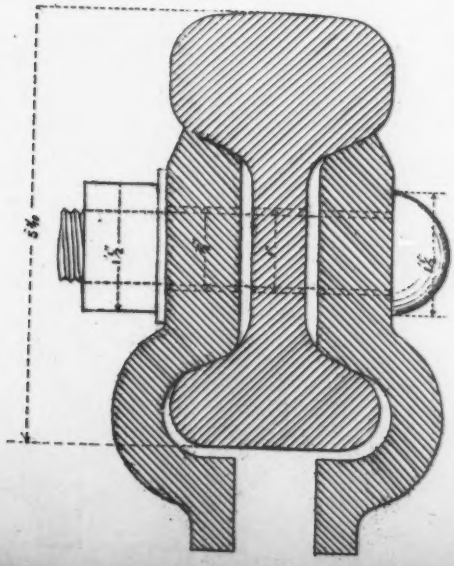
TRANSVERSE SECTION



GREAT NORTHERN RAILWAY

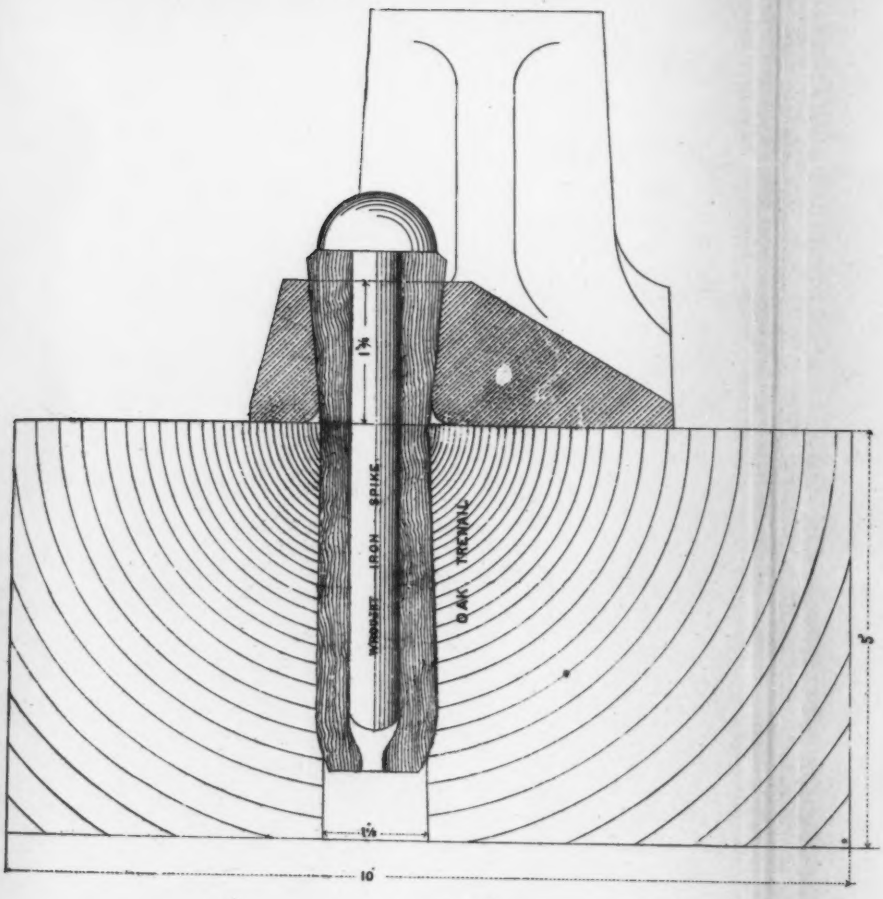


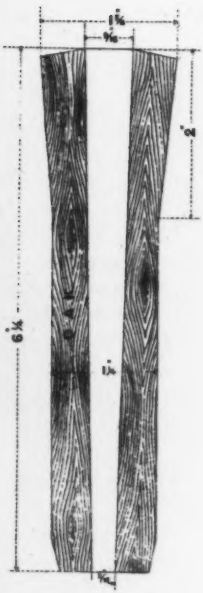
HALF SIZE SECTION OF RAIL & FISH PLATE



DETAILS OF FAST

GREAT EASTERN RA

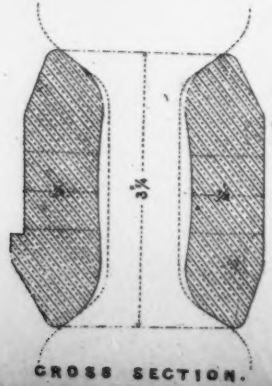




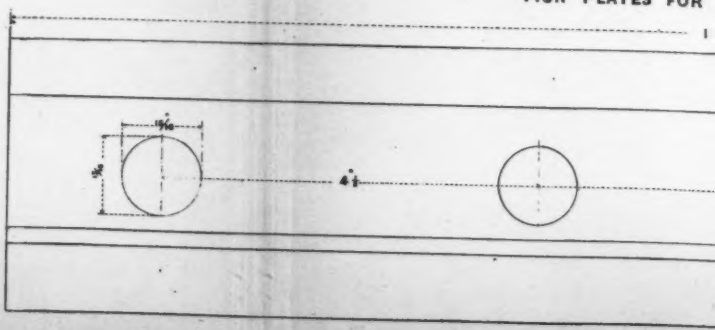
VERTICAL SECTION THRO' TRENAIL.

ELEVAT

FISH PLATES FOR



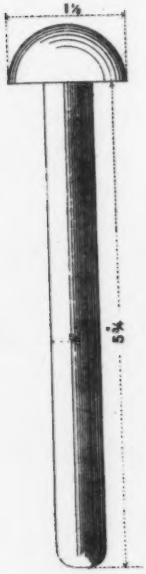
CROSS SECTION.



E L E

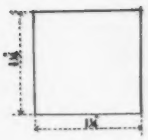
STENINGS.

N RAILWAY

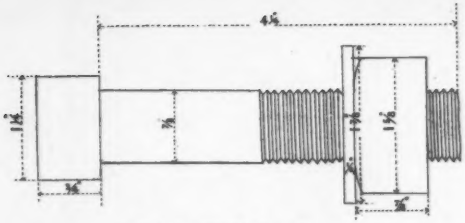


ELEVATION OF SPIKE.

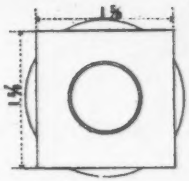
IL.



PLAN OF HEAD



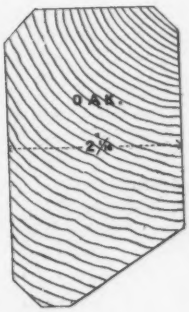
ELEVATION OF FISH BOLT.



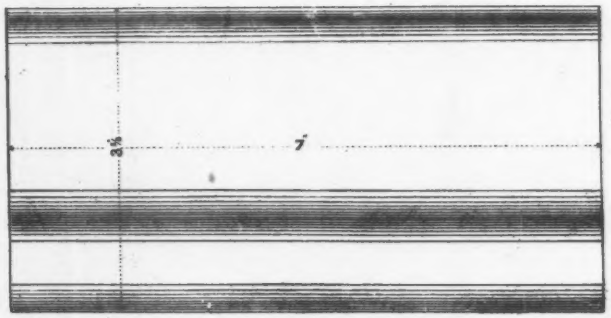
PLAN OF NUT.

WOOD KEY FOR 80 LBS IRON RAIL.

KEYS TO BE MADE OF THIS SECTION THROUGHOUT.



CROSS SECTION.

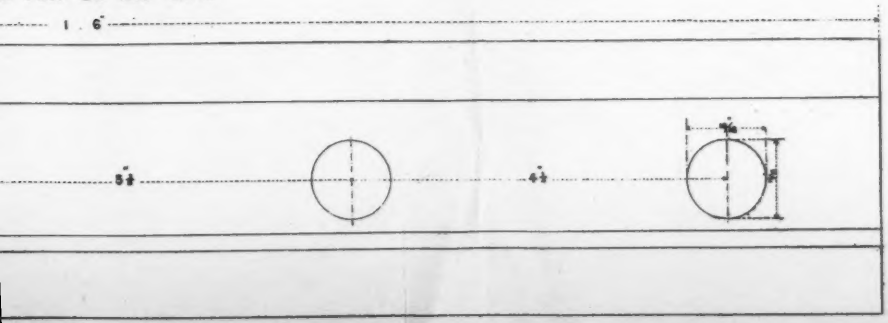


ELEVATION

NOTE.
SIDES OF KEY TO BE PARALLEL.

	LBS.	OZ.
WEIGHT OF ONE SPIKE		10
PAIR OF FISH PLATES	2	3
FISH BOLT, NUT & WASHER		1½

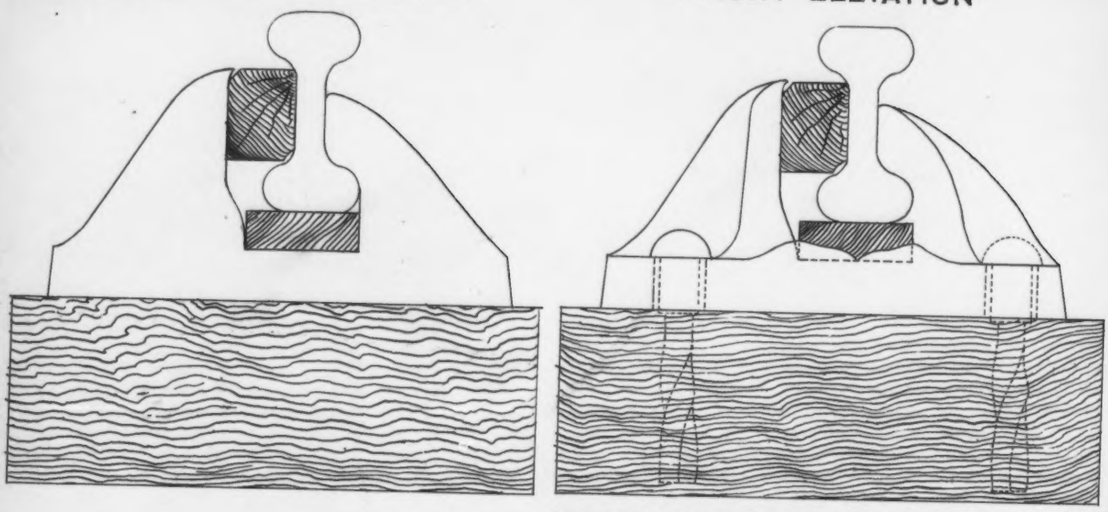
S FOR 80 LBS RAIL.



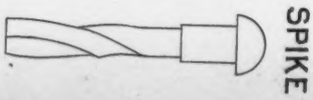
ELEVATION.

LONGITUDINAL SECTION

FRONT ELEVATION



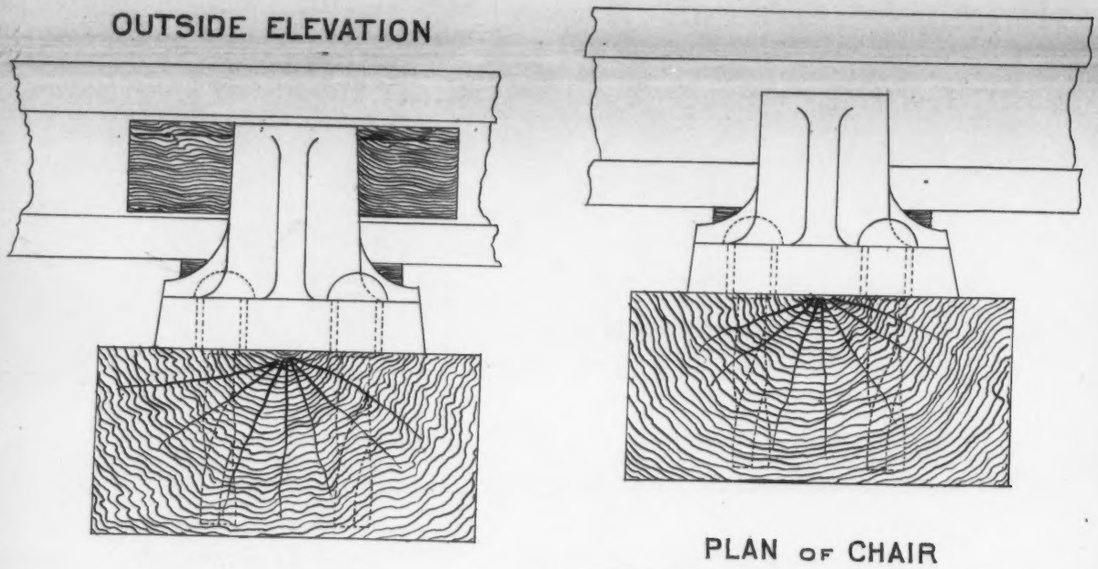
NORTH EASTERN RAIL WAY



SPIKE

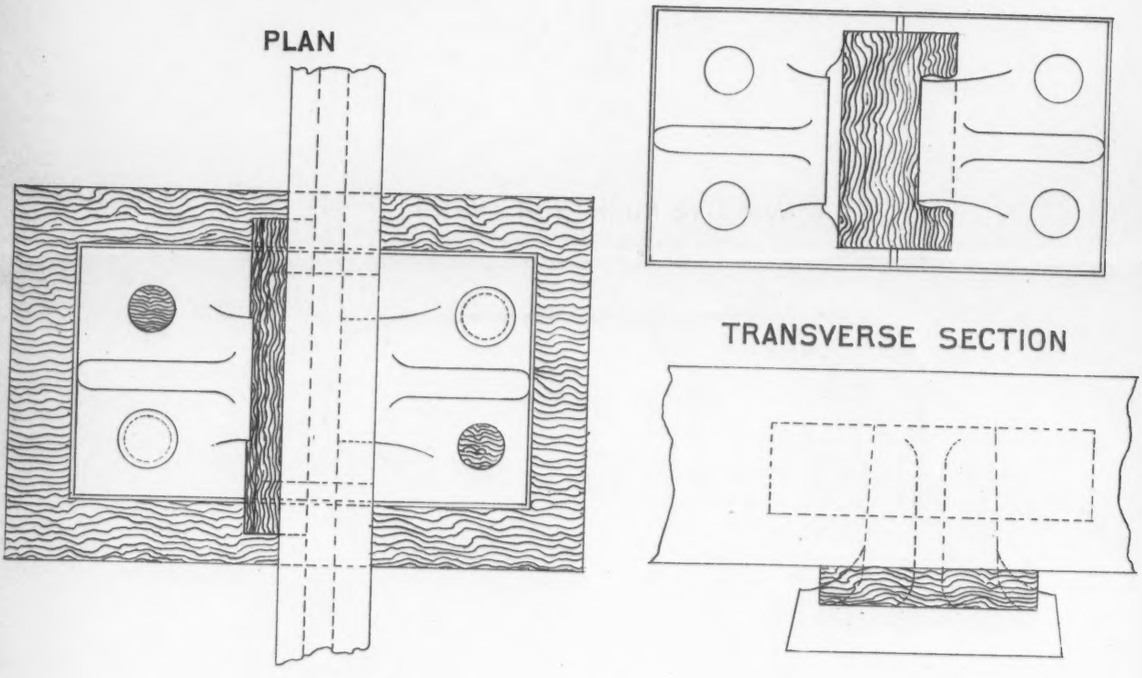
INSIDE ELEVATION

OUTSIDE ELEVATION

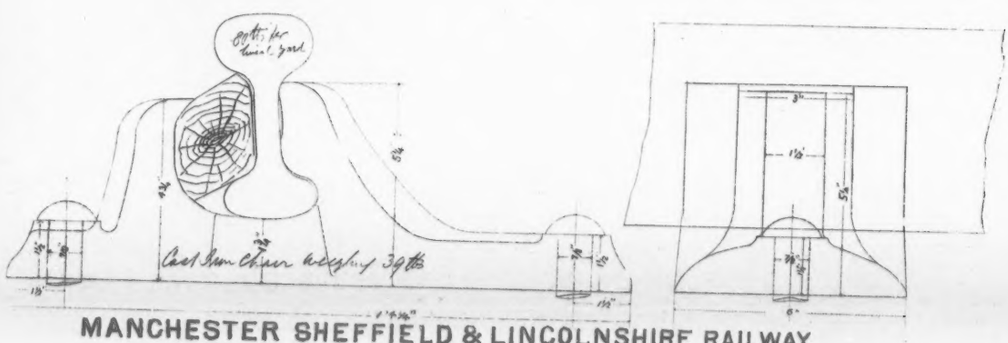


PLAN OF CHAIR

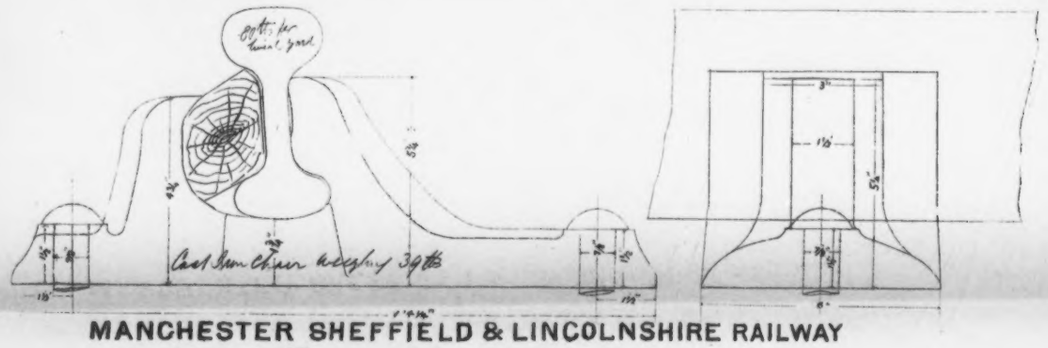
PLAN



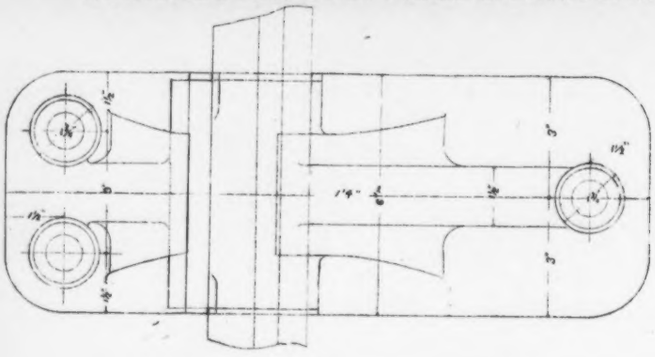
TRANSVERSE SECTION



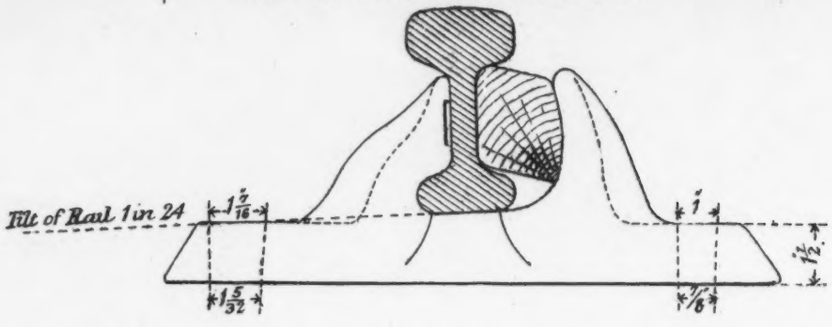
MANCHESTER SHEFFIELD & LINCOLNSHIRE RAILWAY



MANCHESTER SHEFFIELD & LINCOLNSHIRE RAILWAY



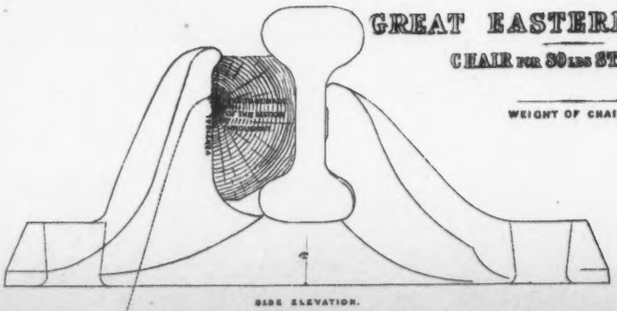
GREAT NORTHERN RAILWAY



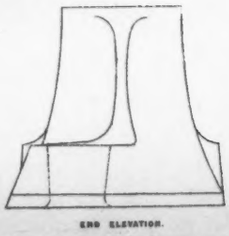
GREAT EASTERN RAILWAY.

CHAIR FOR 80 LBS STEEL RAIL

WEIGHT OF CHAIR=36 LBS.

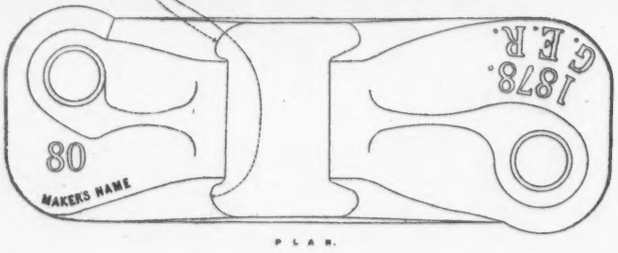


SIDE ELEVATION.



END ELEVATION.

THESE EDGES TO BE ROUNDED OFF SLIGHTLY SO AS NOT TO CUT THE KEYS.



PLAN.

PLATE VIII
TRANS. AM. SOC. CIV. ENGR'S.
VOL. VIII No. CLXXVI
BOGART ON PERMANENT WAY
Scale ¼ full size

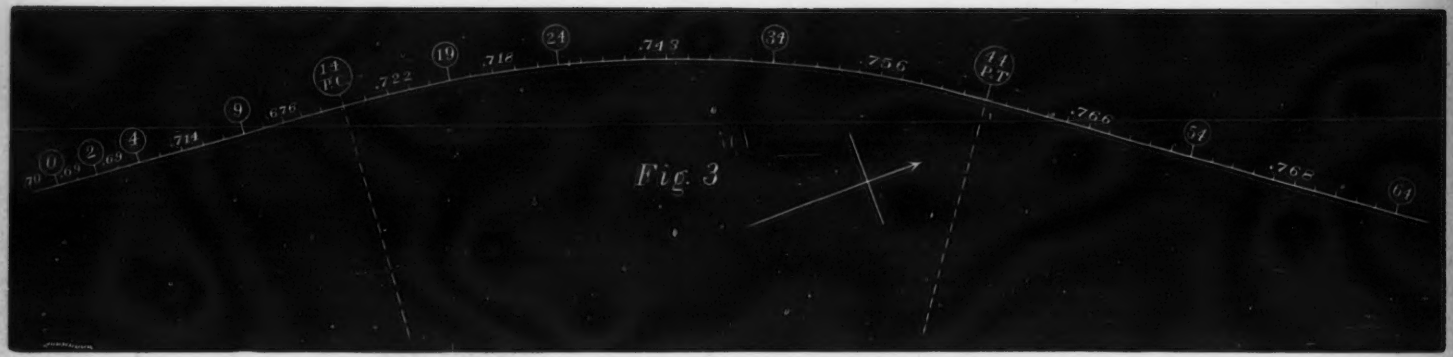
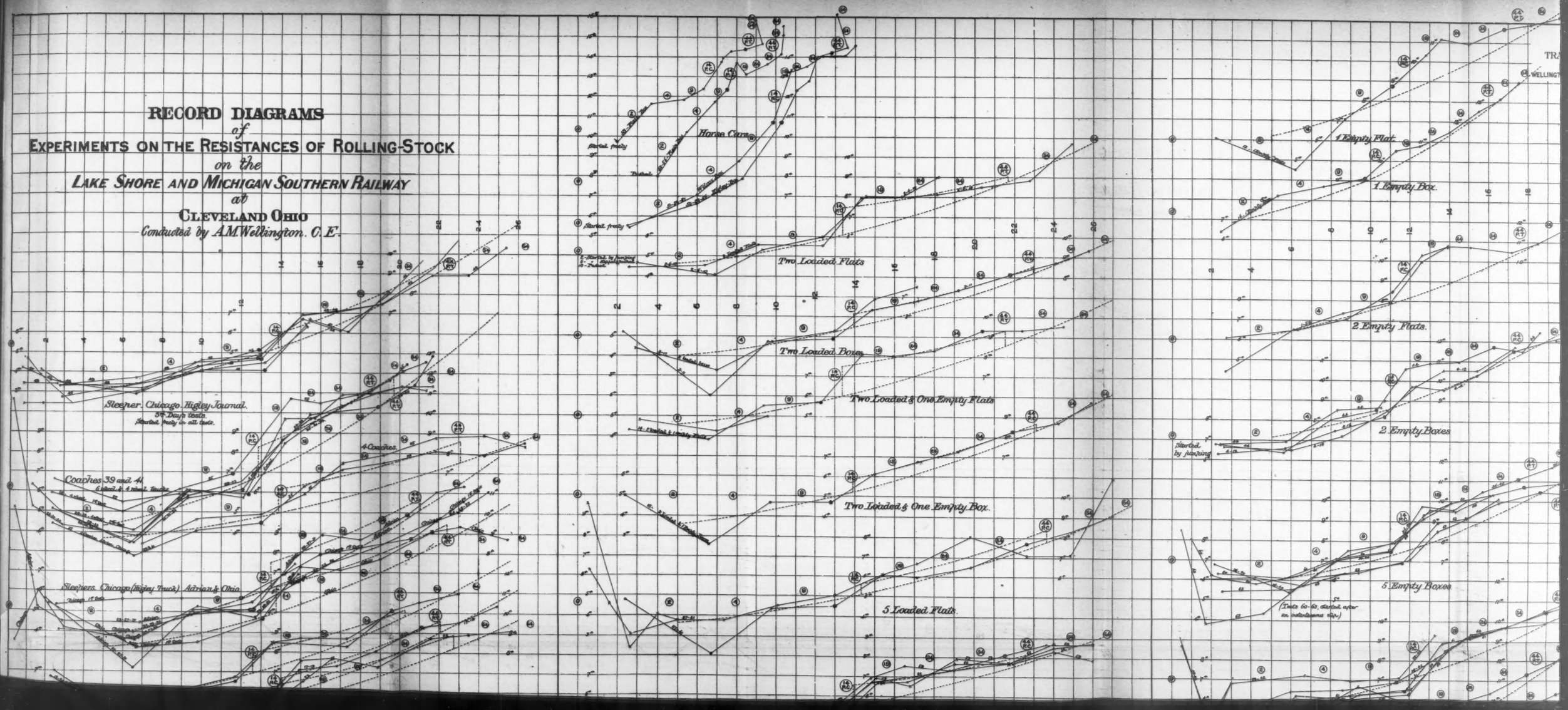


Fig. 3

Figures in circles show the stations at which observations were taken, the starting point for all tests being 0. The figures also show the distance of each station from the starting point, in hundred feet. Decimals between stations show the average rate of grade per 100 feet.

RECORD DIAGRAMS
of
EXPERIMENTS ON THE RESISTANCES OF ROLLING-STOCK
on the
LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY
at
CLEVELAND OHIO

Conducted by A.M. Wellington. C.E.



G-STOCK

WAY

Horse Cars

Two Loaded Flats

Two Loaded Boxes

Two Loaded & One Empty Flats

Two Loaded & One Empty Box

5 Loaded Flats

1 Empty Flat.

1 Empty Box.

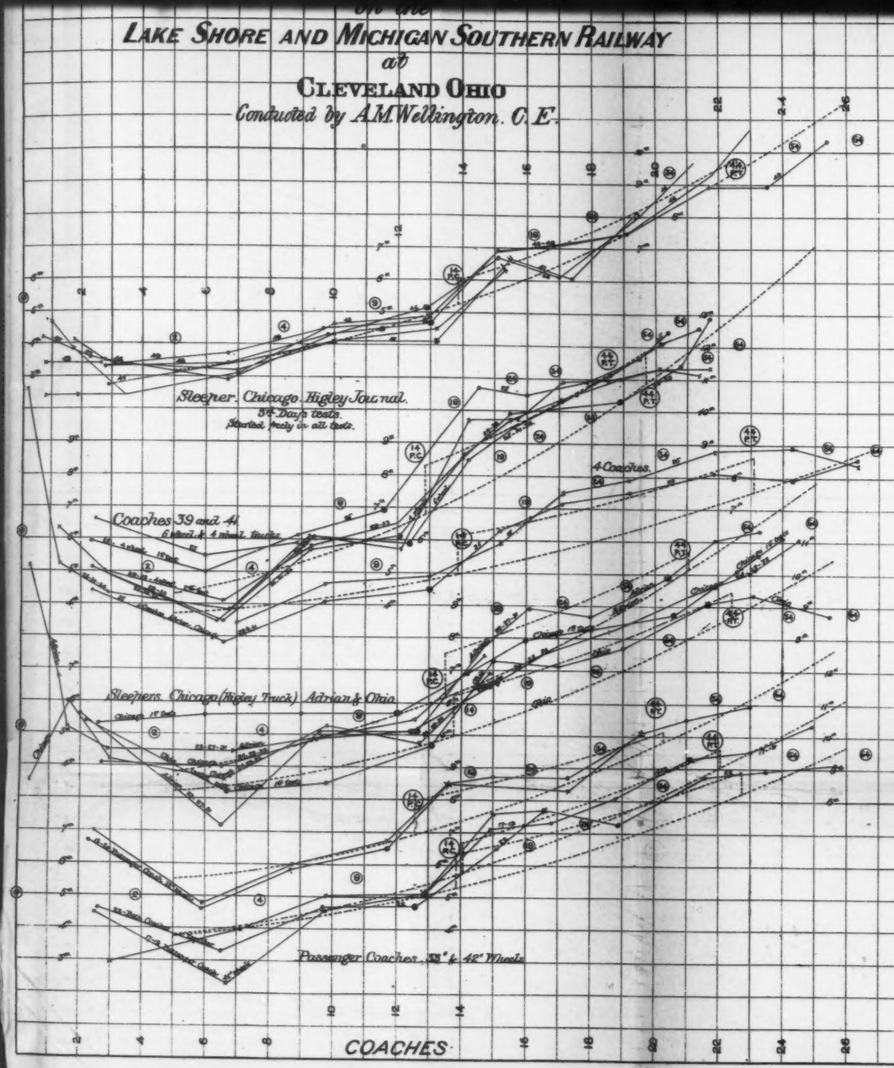
2 Empty Flats.

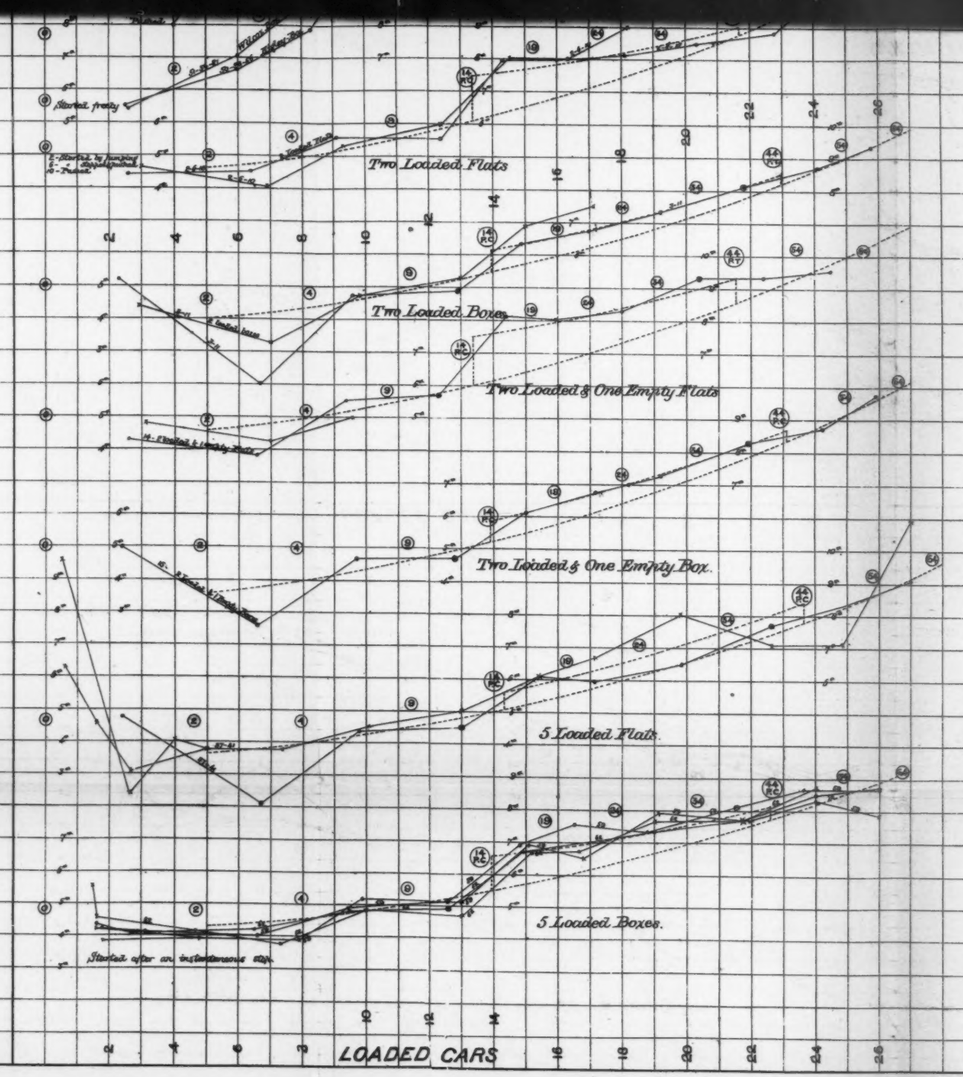
2 Empty Boxes

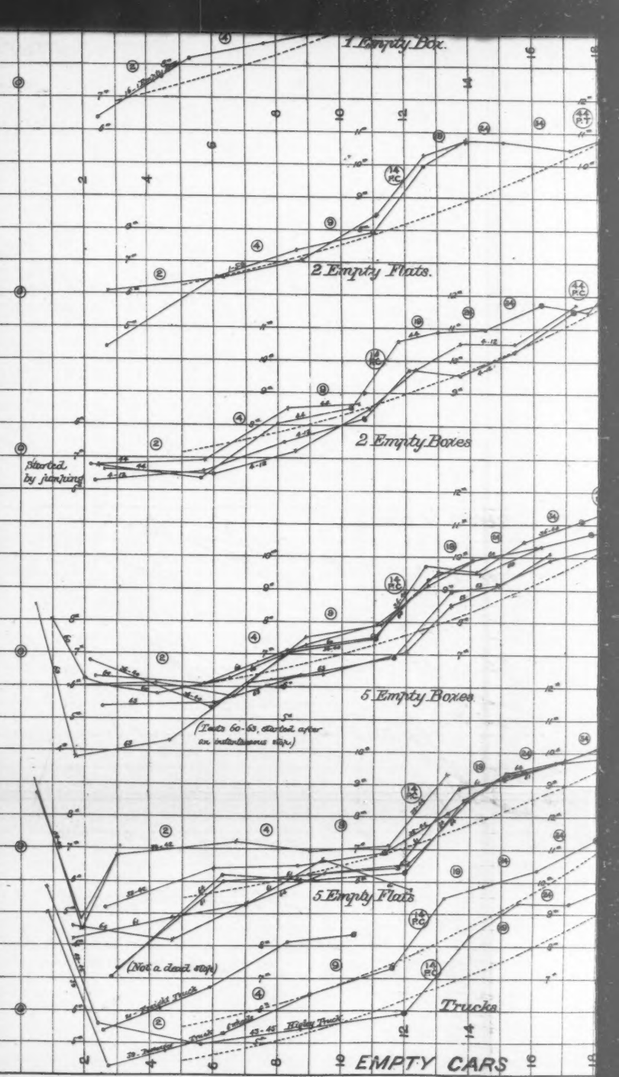
5 Empty Boxes

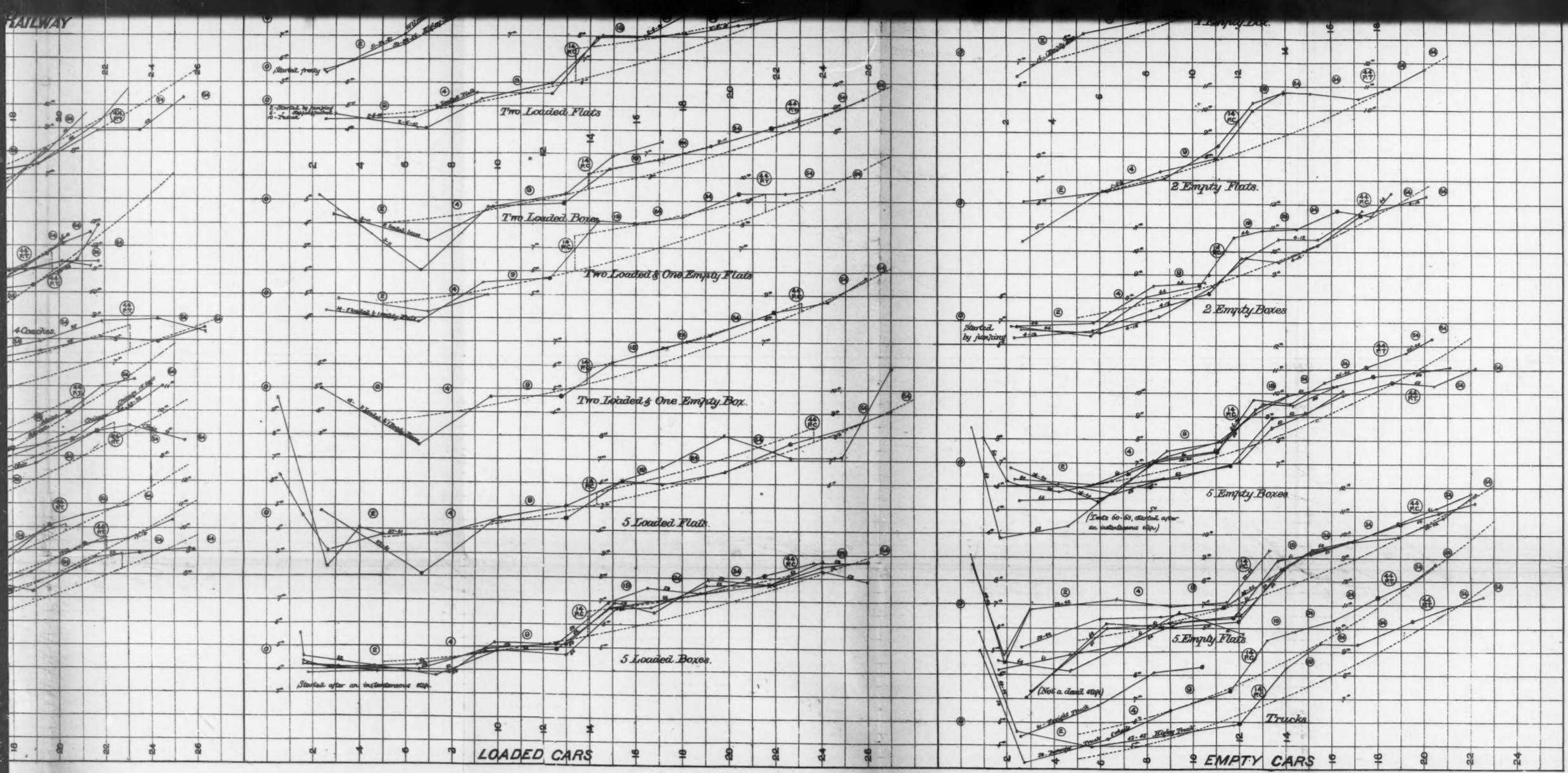
5 Empty Flats

Lake Shore and Michigan Southern Railway
at
Cleveland Ohio
Conducted by A.M. Wellington. C.E.


Sleeper. Chicago Higley Journal.
5th Days tests.
Started, freely in all tests.
4 Coaches.
Coaches 39 and 41
Sleepers. Chicago (Higley Truck) Adrian & Ohio.
Passenger Coaches. 33" & 42" Wheels.
COACHES






RAILWAY
4-Coaches.
Two Loaded Flats.
Two Loaded Boxes.
Two Loaded & One Empty Flats.
Two Loaded & One Empty Box.
5 Loaded Flats.
5 Loaded Boxes.
LOADED CARS
1 Empty Box.
2 Empty Flats.
2 Empty Boxes.
5 Empty Boxes.
5 Empty Flats.
Trucks.
EMPTY CARS

DIAGRA

showing th

RESISTANCES PER TON OF AMER

as deduced from Exper

LAKE SHORE AND MICHIGAN

at

CLEVELAND

Conducted by A.M.W

30 lbs per ton = Grade of 0.6 per 100

28 " " = " 0.56 per 100

26 " " = " 0.52 per 100

24 " " = " 0.48 per 100

22 " " = " 0.44 per 100

20 " " = " 0.4 per 100

18 " " = " 0.36 per 100

16 " " = " 0.32 per 100

14 " " = " 0.28 per 100

12 " " = " 0.24 per 100

10 " " = " 0.2 per 100

8 " " = " 0.16 per 100

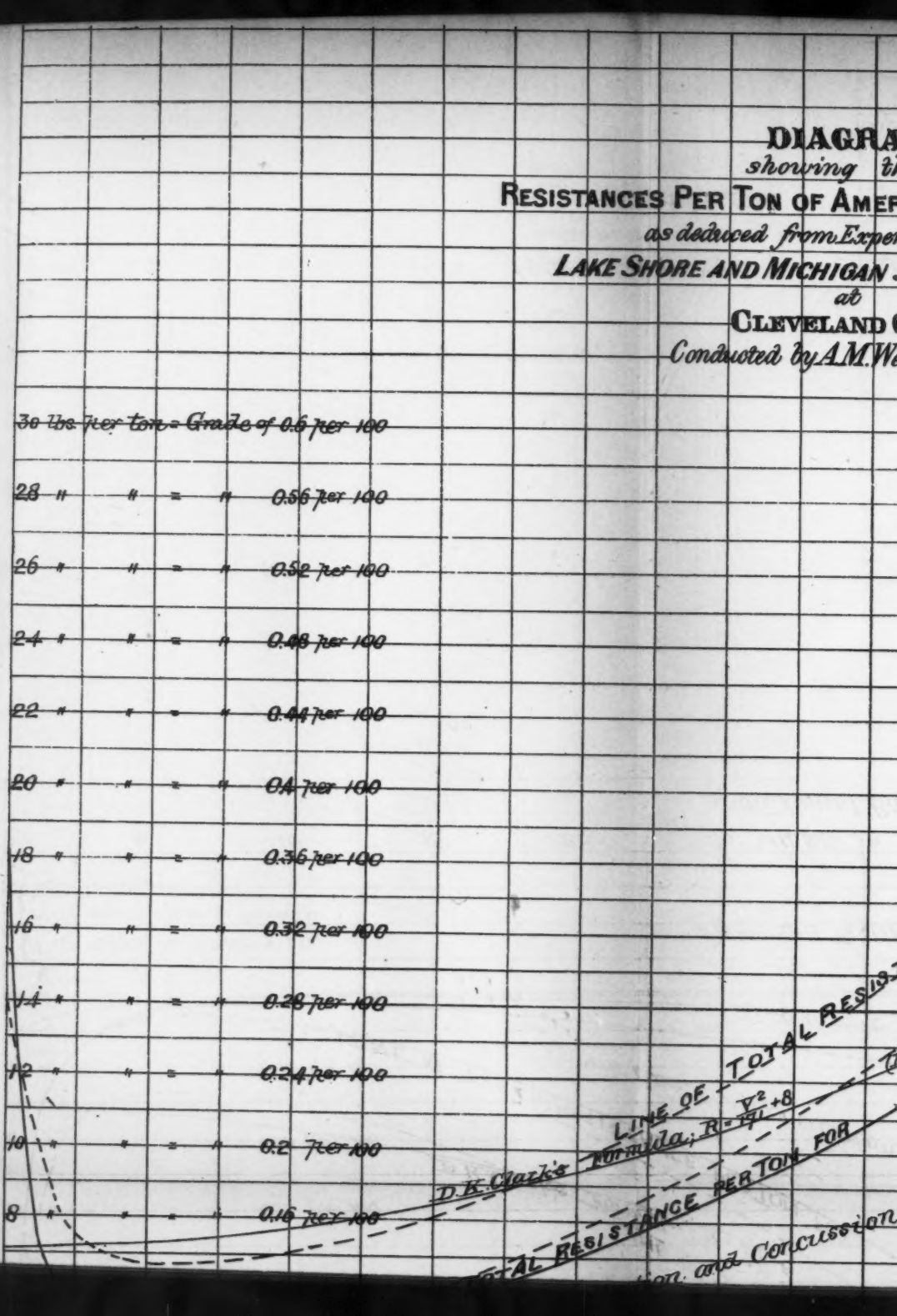
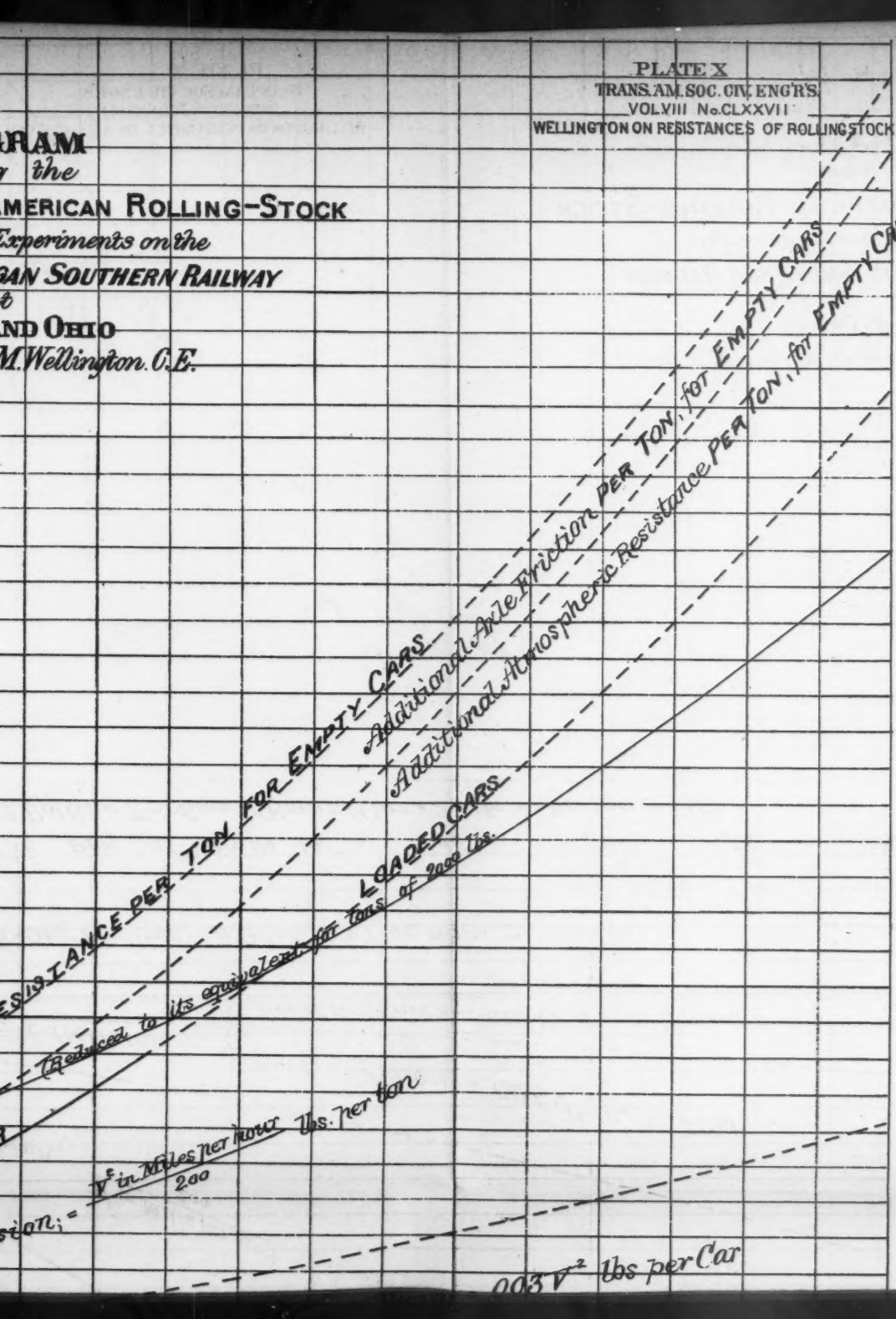
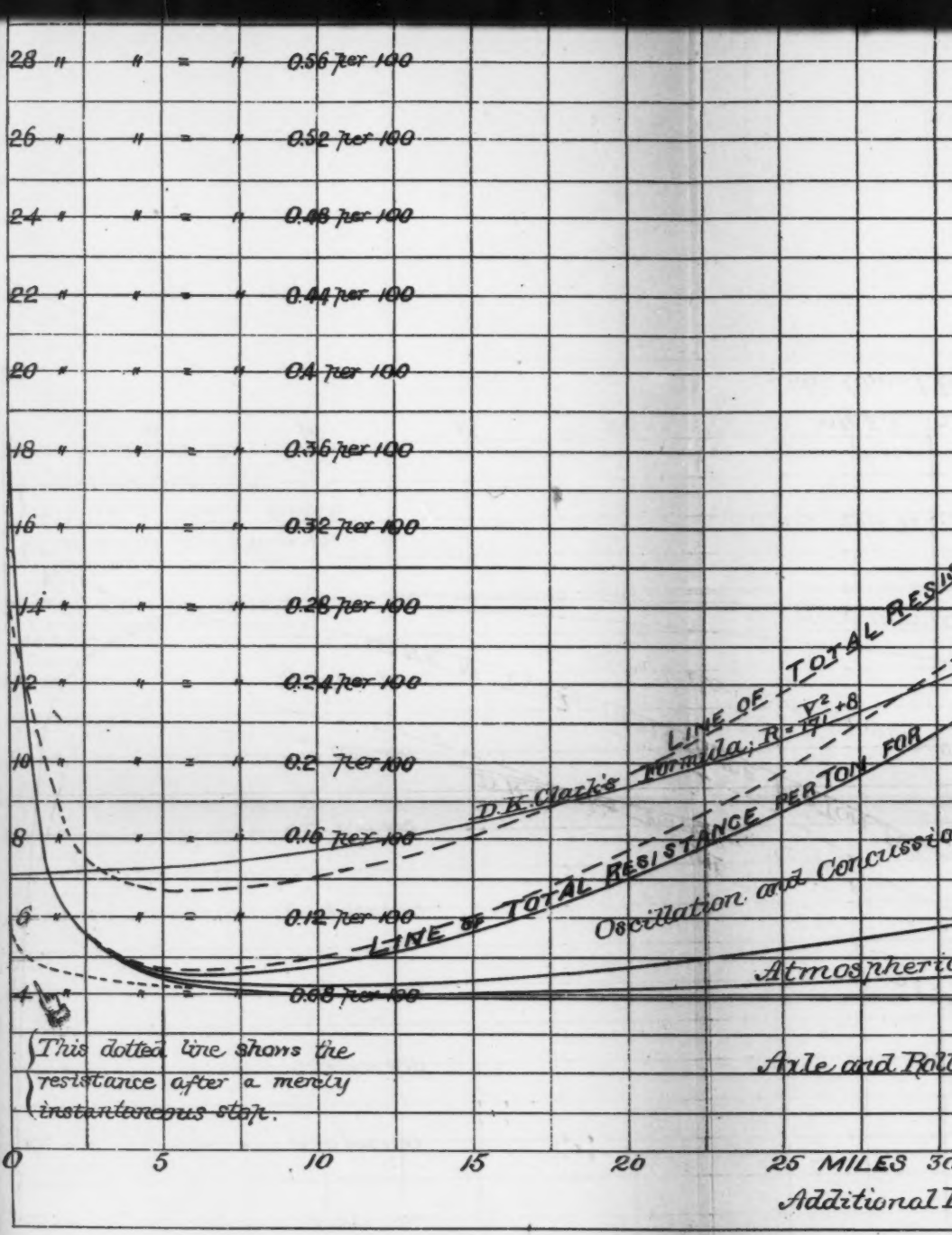
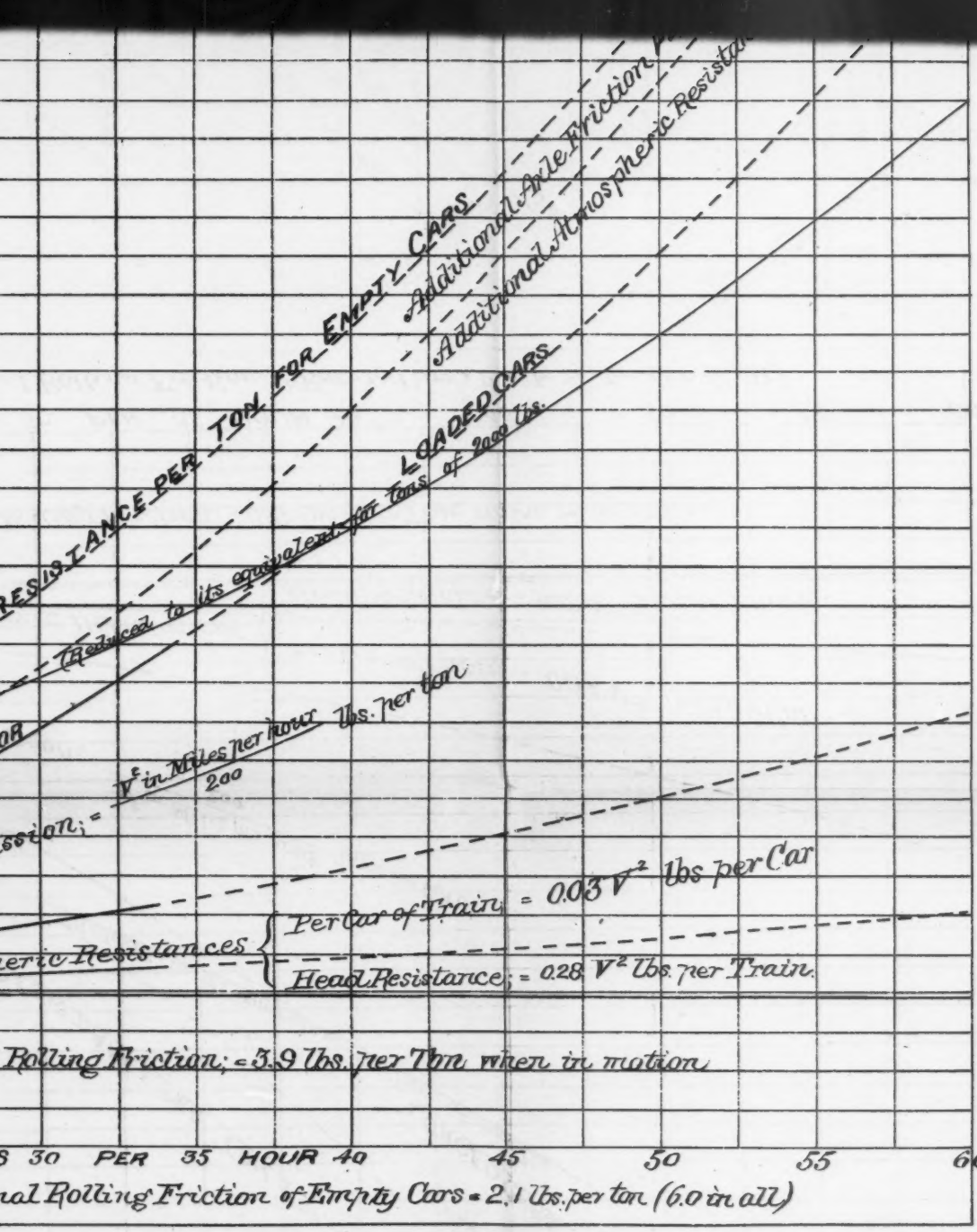


PLATE X
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII No. CLXXVII
WELLINGTON ON RESISTANCES OF ROLLING STOCK.

RAM
the
MERICAN ROLLING-STOCK
Experiments on the
AN SOUTHERN RAILWAY
t
ND OHIO
M. Wellington. C.E.

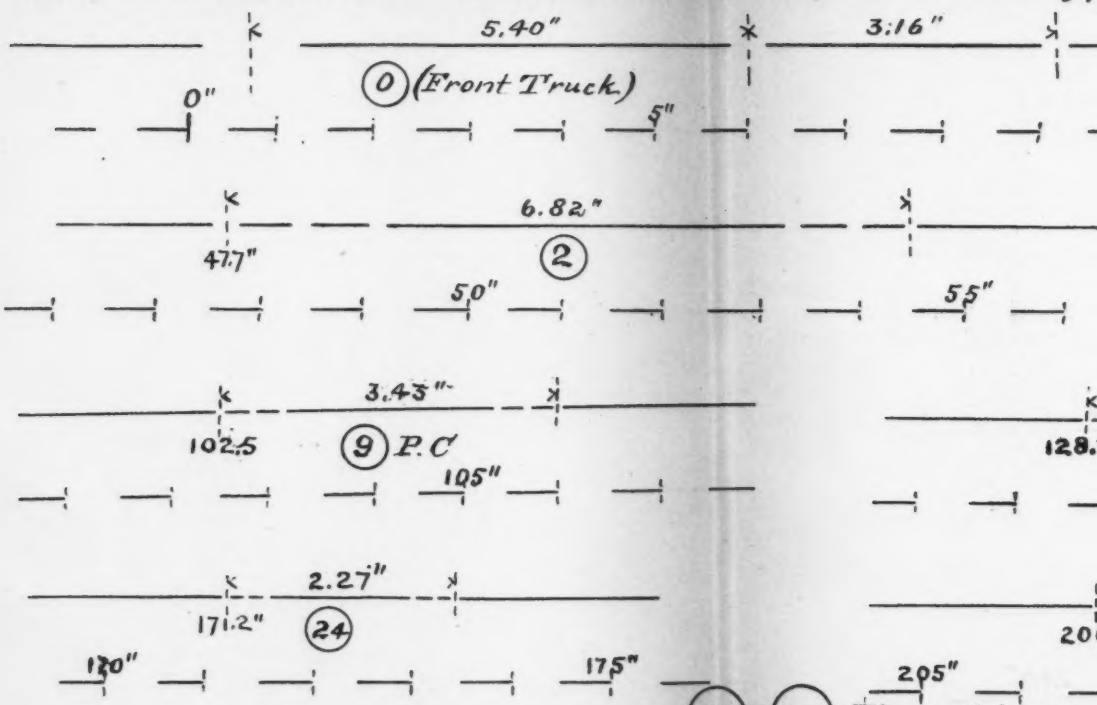

Additional Axle Friction per Ton, for Empty Cars
Additional Atmospheric Resistance per Ton, for Empty Cars
Additional for Loaded Cars
(Reduced to its equivalent for tons of 2000 lbs.
V² in Miles per hour / 200 lbs. per ton
.003 V² lbs per Car


28 " " = " 0.56 per 100
26 " " = " 0.52 per 100
24 " " = " 0.48 per 100
22 " " = " 0.44 per 100
20 " " = " 04 per 100
18 " " = " 0.36 per 100
16 " " = " 0.32 per 100
14 " " = " 0.28 per 100
12 " " = " 0.24 per 100
10 " " = " 0.2 per 100
8 " " = " 0.16 per 100
6 " " = " 0.12 per 100
4 " " = " 0.08 per 100
D.K. Clark's Formula; R = 4f + V² +8
LINE OF TOTAL RESISTANCE PER TON FOR
LINE OF TOTAL RESISTANCE
Oscillation and Concussio
Atmospheri
Axle and Roll
This dotted line shows the resistance after a merely instantaneous stop.
0
5
10
15
20
25 MILES 30
Additional


RESISTANCE PER TON FOR EMPTY CARS
Additional Axle Friction
Additional Atmospheric Resista
Reduced to its equivalent for tons of 2000 lbs.
LOADED CARS
ession; = V² in Miles per hour / 200 lbs. per ton
Per Car of Train = 0.03 V² lbs per Car
Head Resistance; = 0.28 V² lbs. per Train.
Rolling Friction; = 3.9 lbs. per Ton when in motion
30 PER 35 HOUR 40 45 50 55 60
nal Rolling Friction of Empty Cars = 2.1 lbs. per ton (6.0 in all)

Telegraphic Record of Test No. 48

Sleeping Coach "Chicago" fitted with Higley Patent Roller Bearings. Tot
Wheel base of each truck 10.67 ft. weight 68000 lbs.
The upper lines give the telegraphic record of the passage of each wheel ov
line gives the synchronous telegraphic record of the seconds pendulum.
stations at which records were taken, and the distance from the starting p

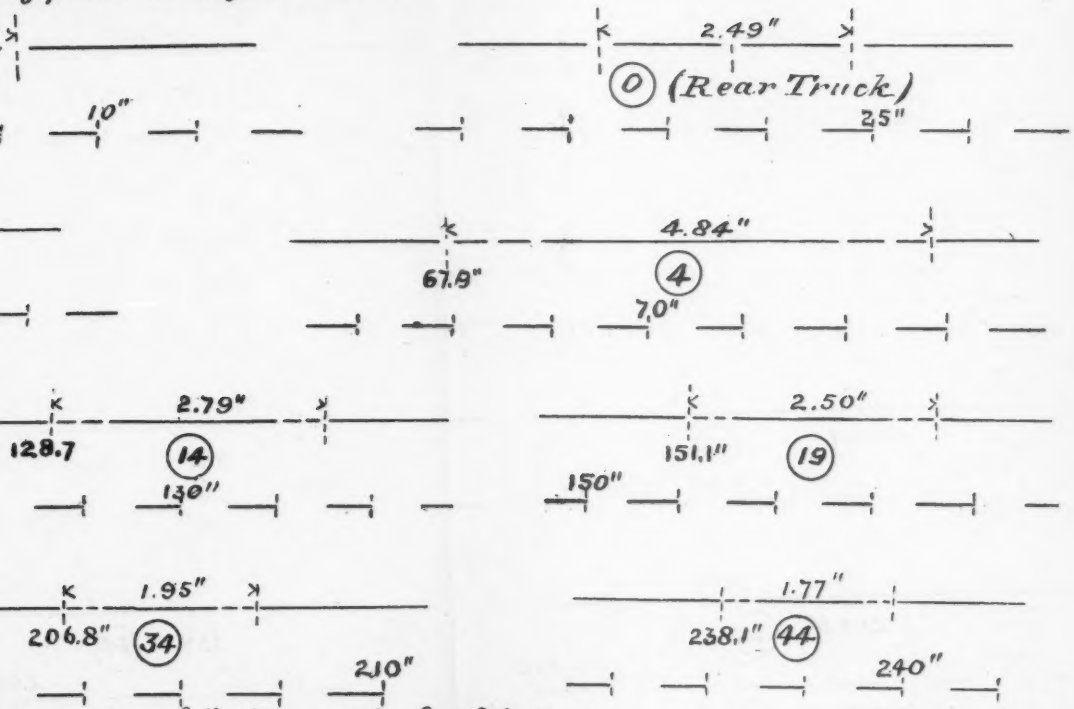


54 & 64 *Telegraphic appa*

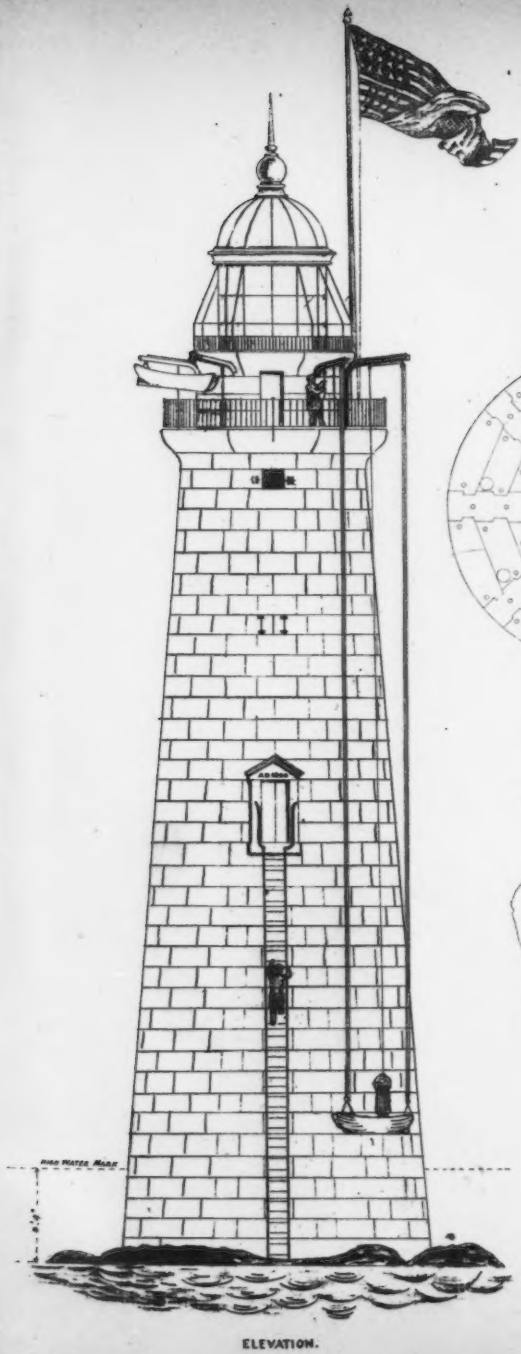
Note: The recording instrument as now improve
of each other affording much greater ac

Total length of wheel base 59.2 ft.

el over each station. The lower
um. Figures in circles show the
ing point in 100 ft. stations.



apparatus failed to work for this test
proved brings the car record and seconds record within 1/8 inch
er accuracy but has not yet been used.



ELEVATION.

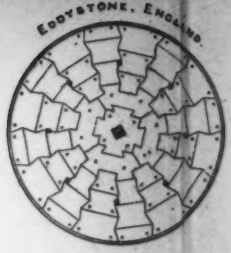
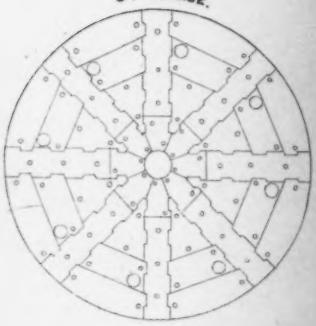


Fig. 3.
3ᴰ COURSE.



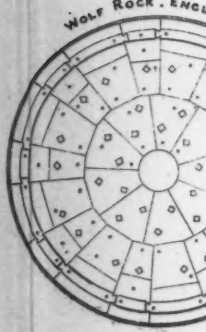
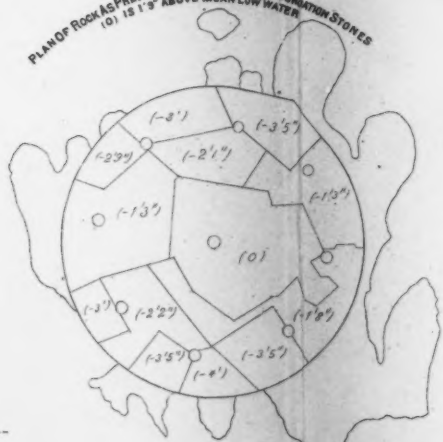


Fig. 1.
PLAN OF ROCK AS PREPARED TO RECEIVE THE FOUNDATION STONES
(0) IS 1'9" ABOVE MEAN LOW WATER.

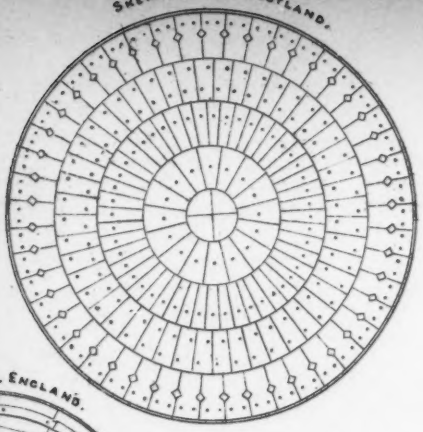


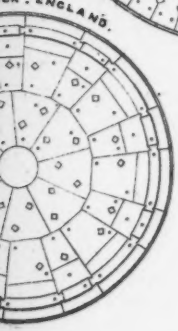
SCALE ½ INCH = ONE FOOT

MINOT'S LEDGE LI

WITH COMPARATIVE SECTIO

SEA ROCK LIGHT





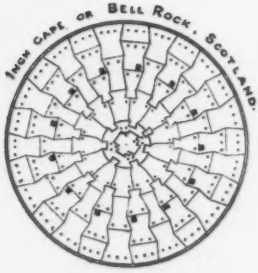
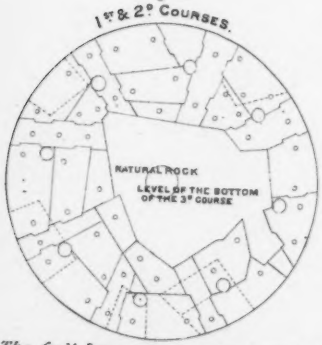
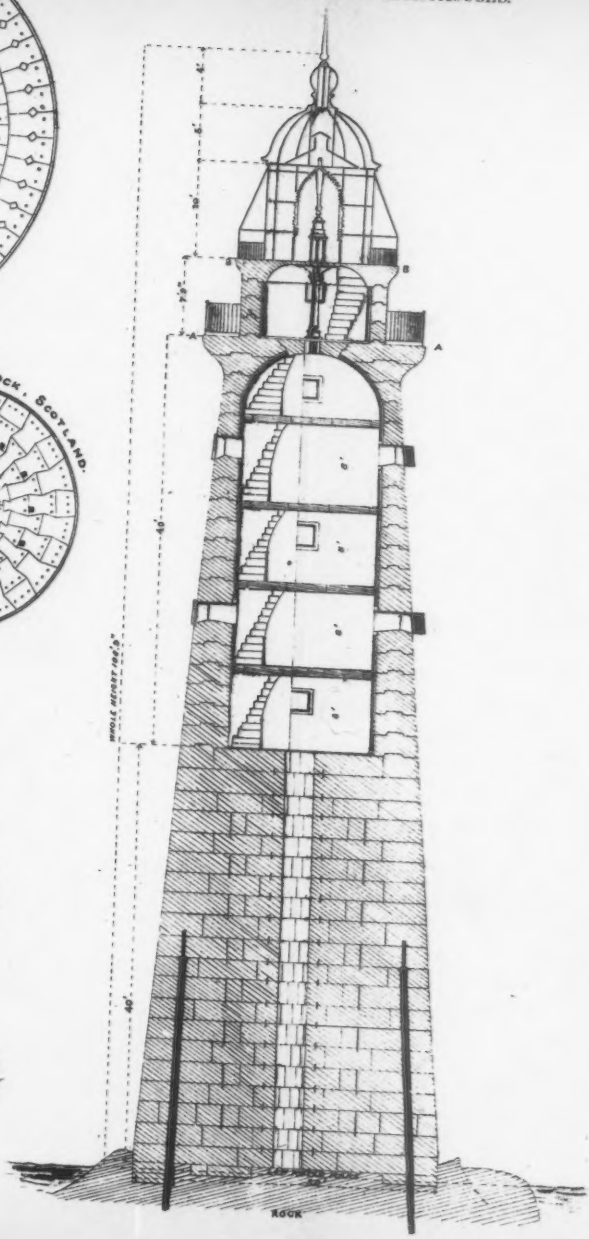


Fig. 2.



The full Lines represent the stones of the second course - the dotted lines represent the seven stones of the first or lowest course.



SECTION

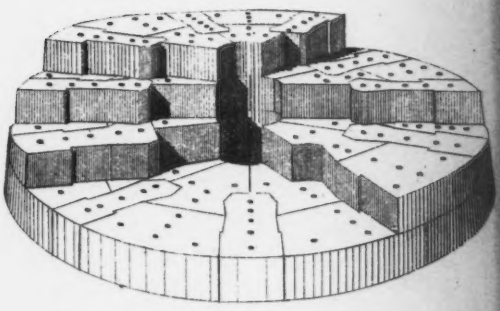
E FOOT.

LIGHT HOUSE

TIONS OF OTHER

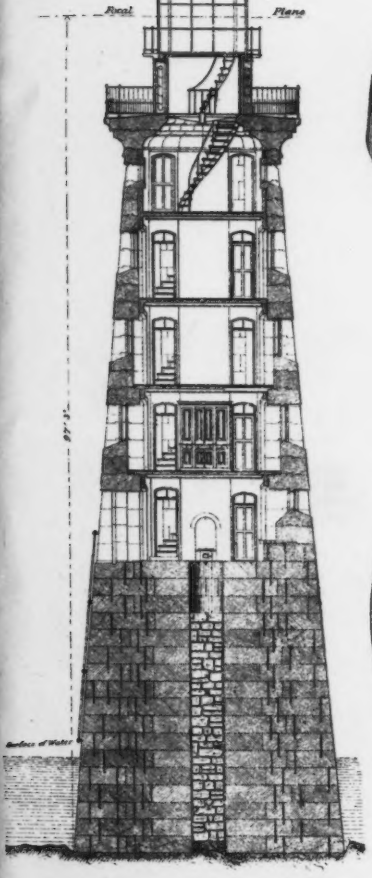
IT HOUSES

DETAILS OF MASONRY.



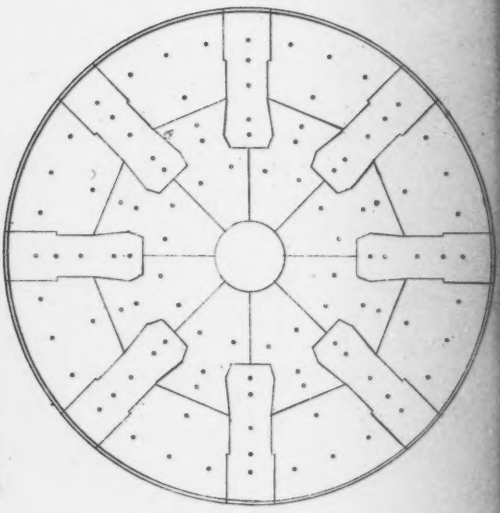
PERSPECTIVE VIEW OF COURSES 14, 15 & 16.

Scale



SECTION.

Scale in feet



GROUND PLAN OF COURSE 14.

LIGHT-HOUSE AT SPECTACLE REEF,
LAKE HURON.

PLATE XIV. BRANDYWINE SHOAL.

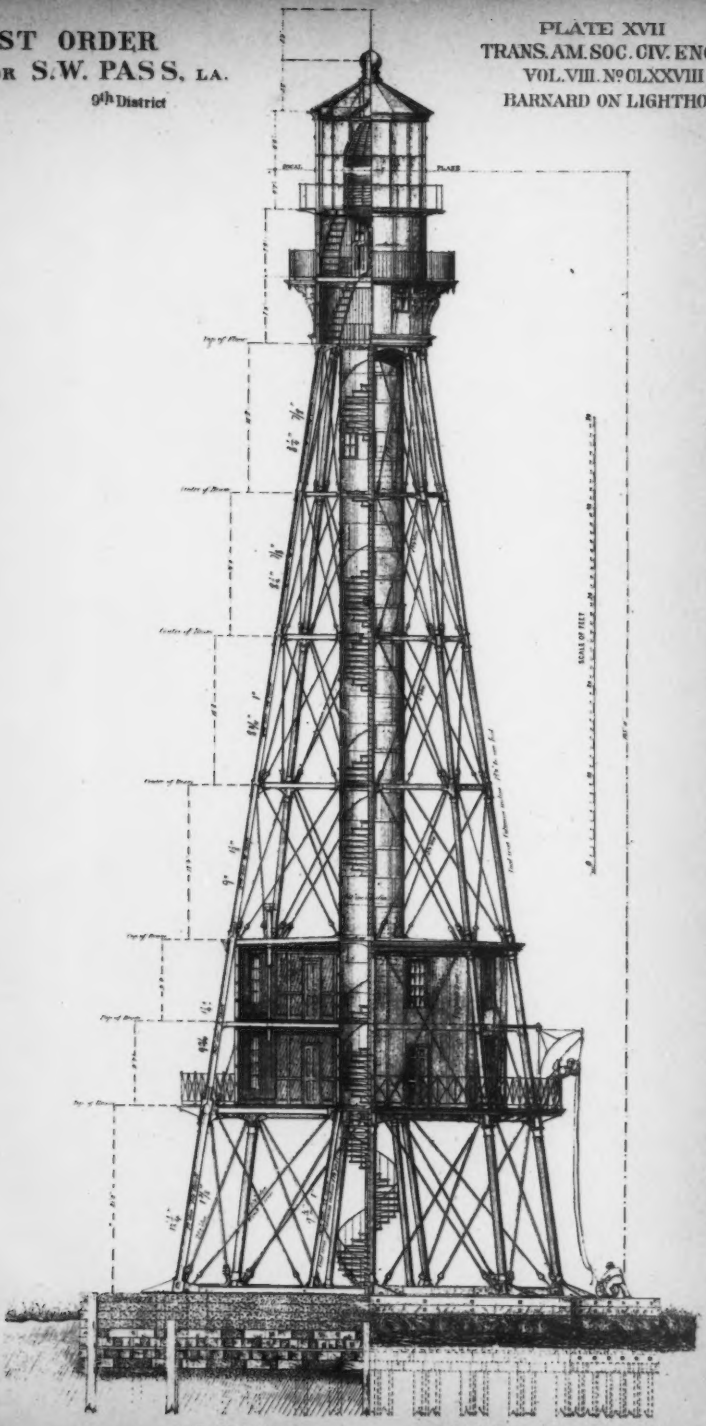
LIGHT HOUSE ON FOWEY ROCKS, FLA.

SHIP SHOAL & TIMBALIER,
GULF OF MEXICO.
8th District.

TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXVIII.
BARNARD ON LIGHTHOUSES.

FIRST ORDER
L. H. FOR S.W. PASS, LA.
9th District

PLATE XVII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXVIII.
BARNARD ON LIGHTHOUSES.



HALF VERTICAL SECTION

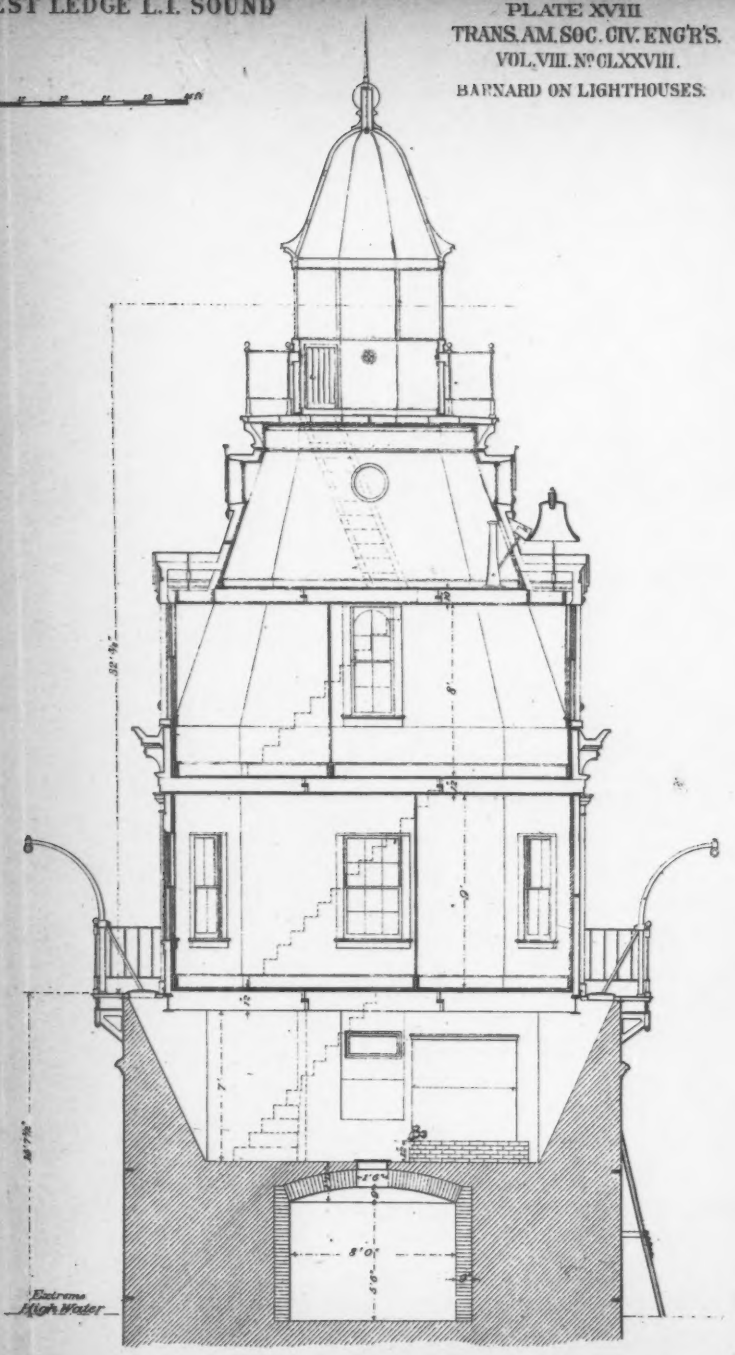
HALF ELEVATION

LIGHT HOUSE FOR SOUTH WEST LEDGE L.I. SOUND

PLATE XVIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXVIII.
BARNARD ON LIGHTHOUSES.

Scale.

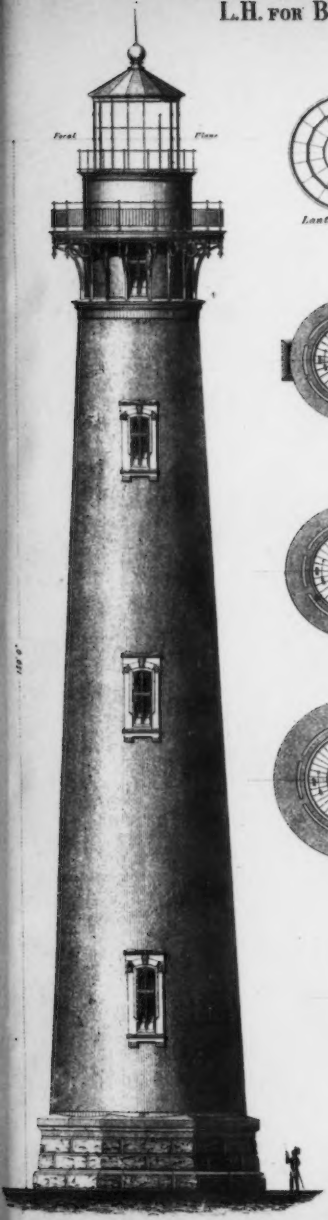
Front Elevation.



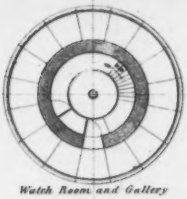
Section.

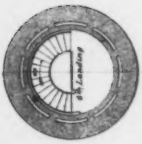
FIRST ORDER
L.H. FOR BODY'S ISLAND, N.C.

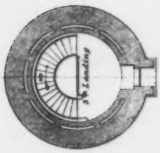
5th District.

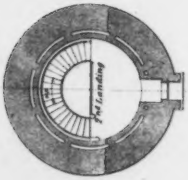


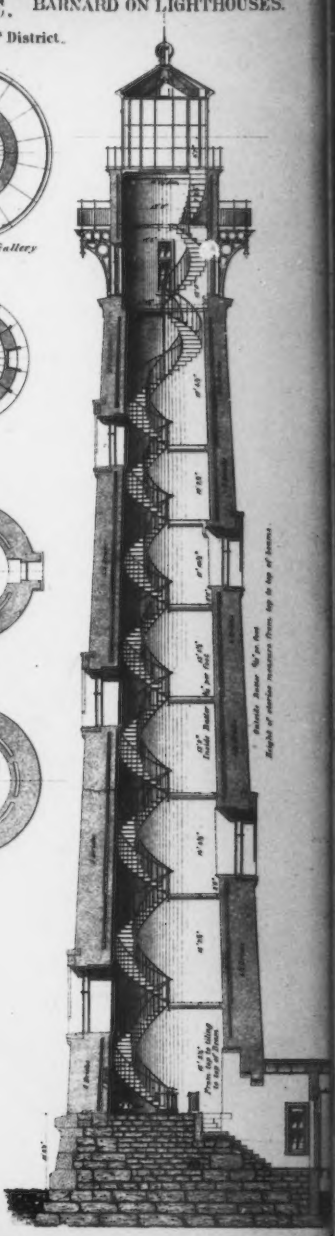
Lantern Gallery


Watch Room and Gallery



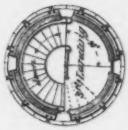




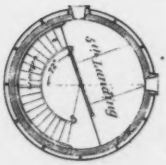


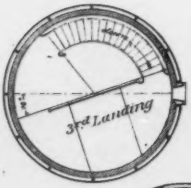
LIGHTHOUSE

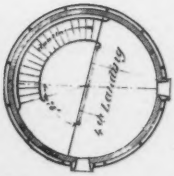
FOR

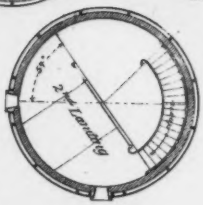


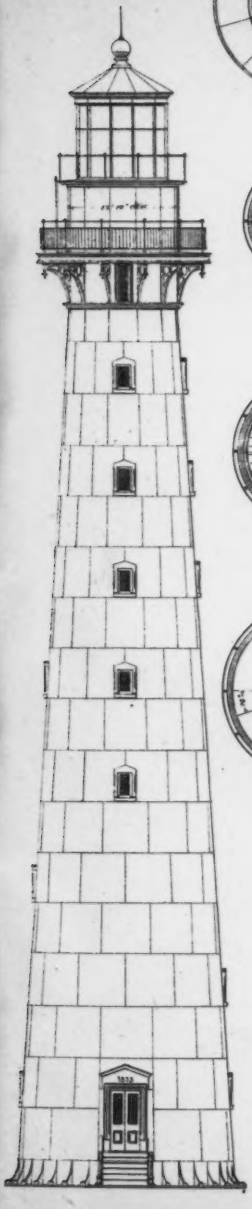
HUNTING ISLAND
S. C.











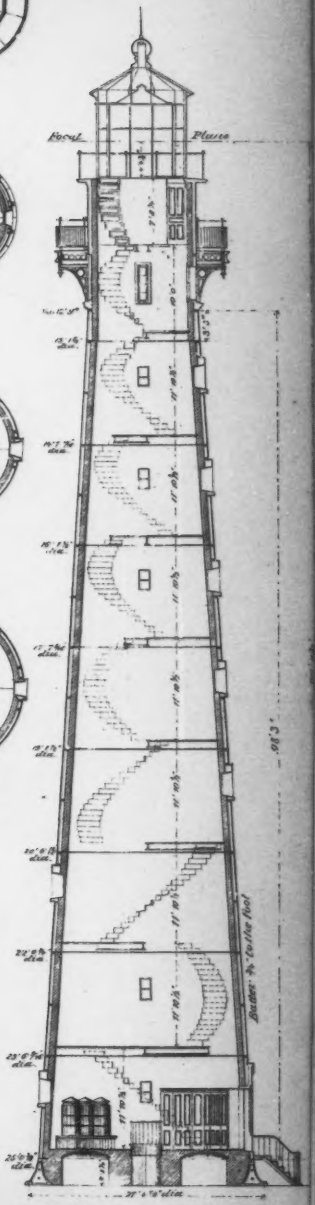
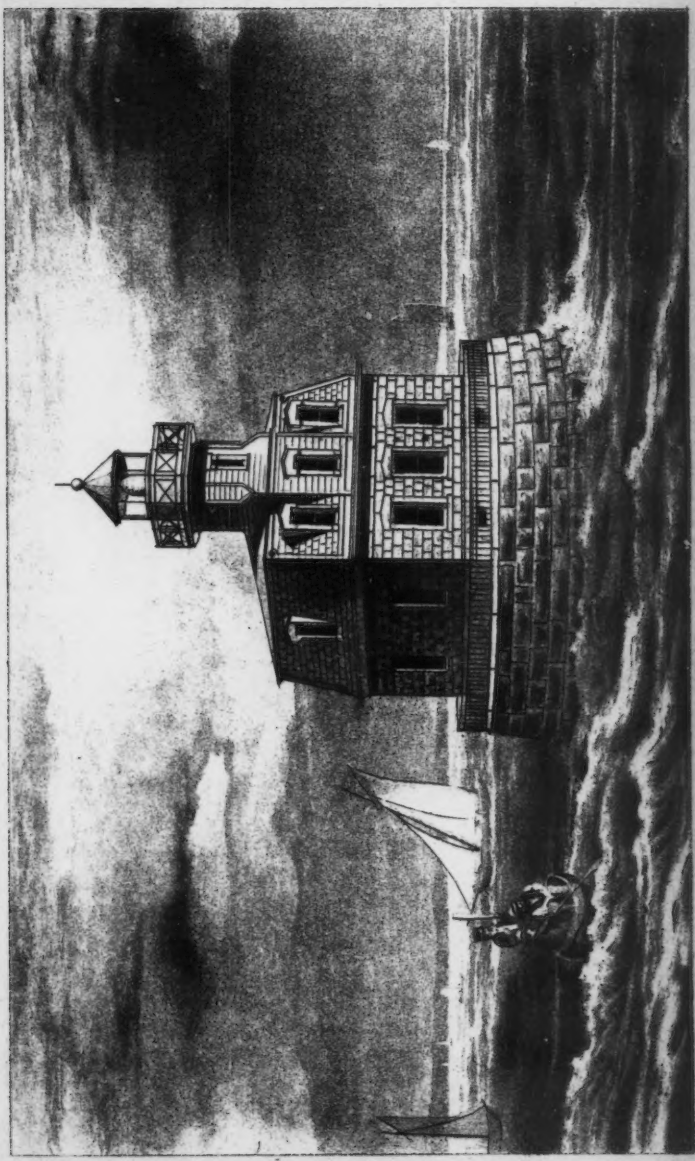


PLATE XXI.

RACE ROCK LIGHTHOUSE.



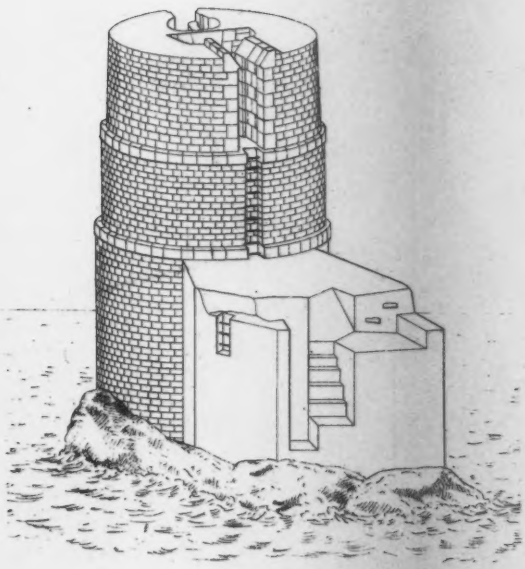
LIGHTHOUSE AT PENFIELD REEF, LONG ISLAND SOUND.

PHARE D'ARMEN

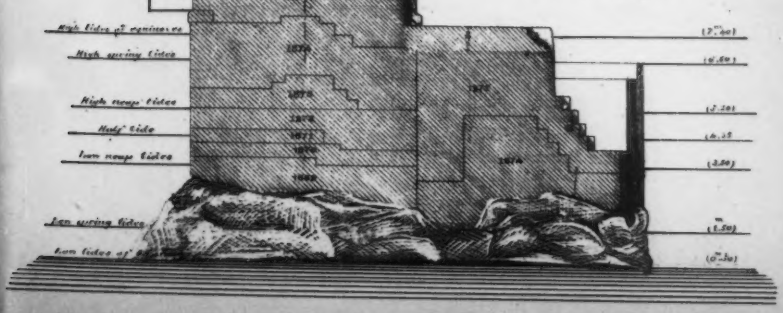
PLATE XXIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXVIII.
BARNARD ON LIGHTHOUSES.

Vertical Section

State of construction
at the end of the working season of
1874.

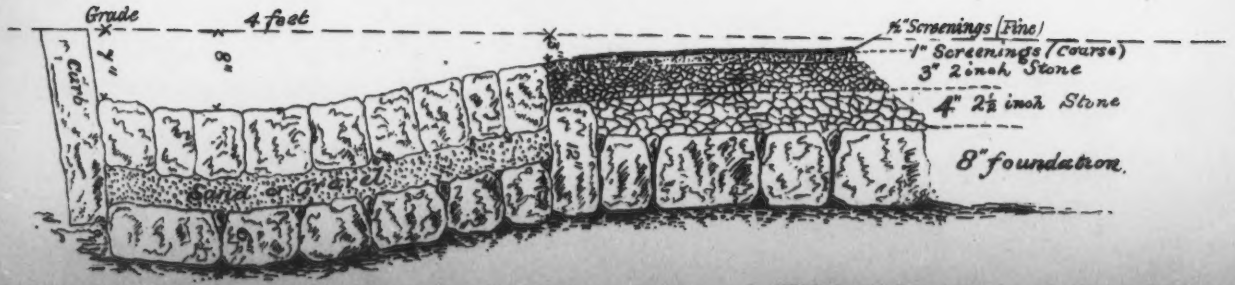


The dimensions are in metres.



Section of Pavement for 5th Avenue from 59th to 72nd Street

Width of Avenue 40 ft.

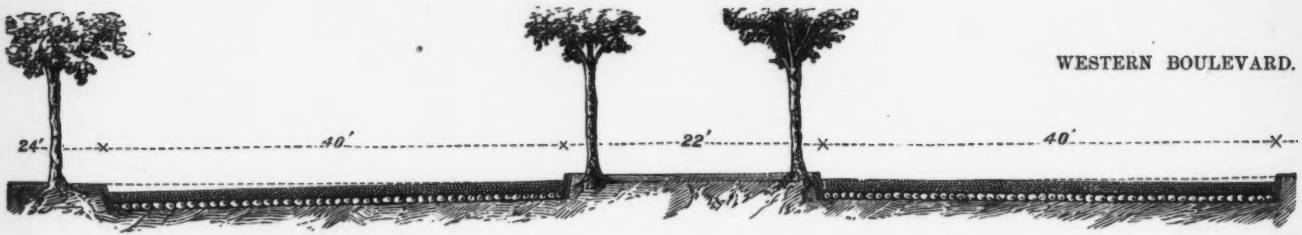


F.H.Hamlin Engineer.

PLATE XXIV
TRANS.AM.SOC.CIV.ENGR'S.
VOL.VIII Nº CLXXX
NORTH ON ROADS

PLATE XXV.

WESTERN BOULEVARD.



SIXTH AVENUE.

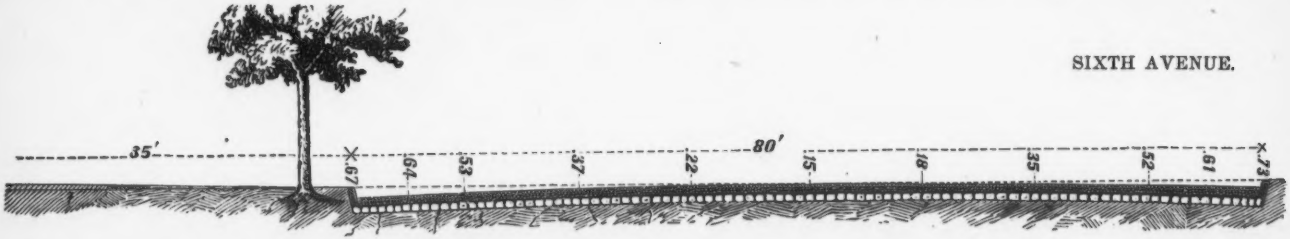
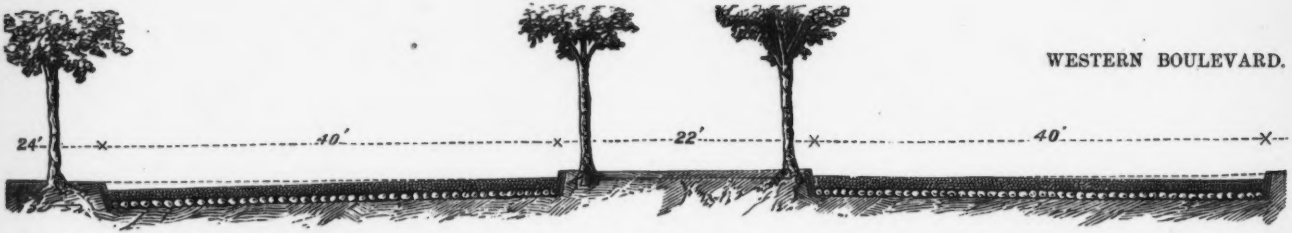
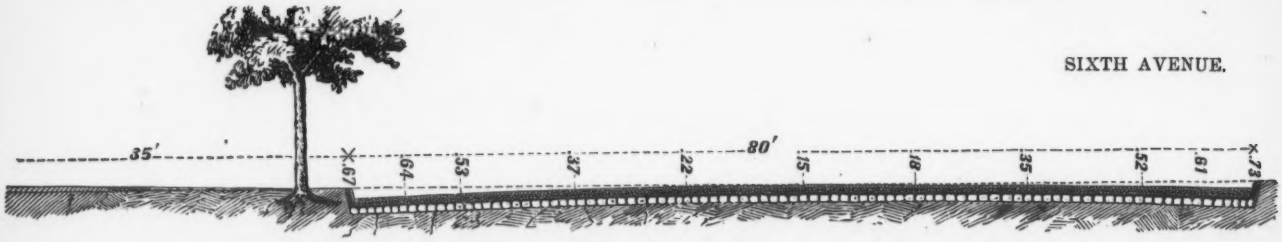


PLATE XXV.

WESTERN BOULEVARD.



SIXTH AVENUE.



THE GELLERAT ROLLER.

FIG. 1.

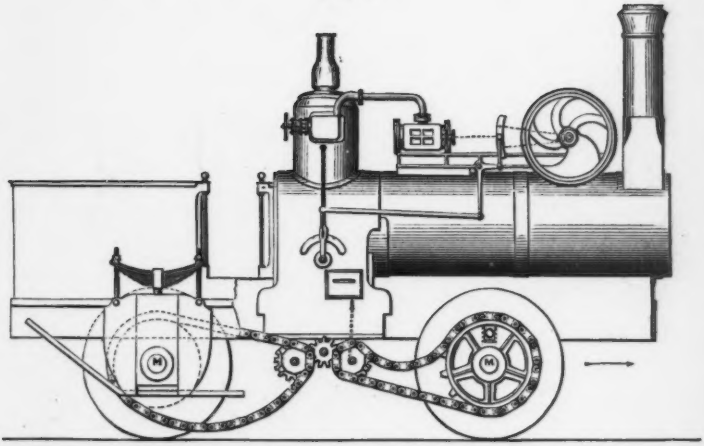


FIG. 2.

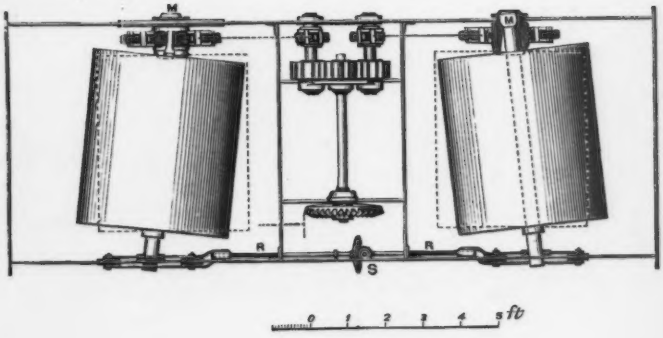


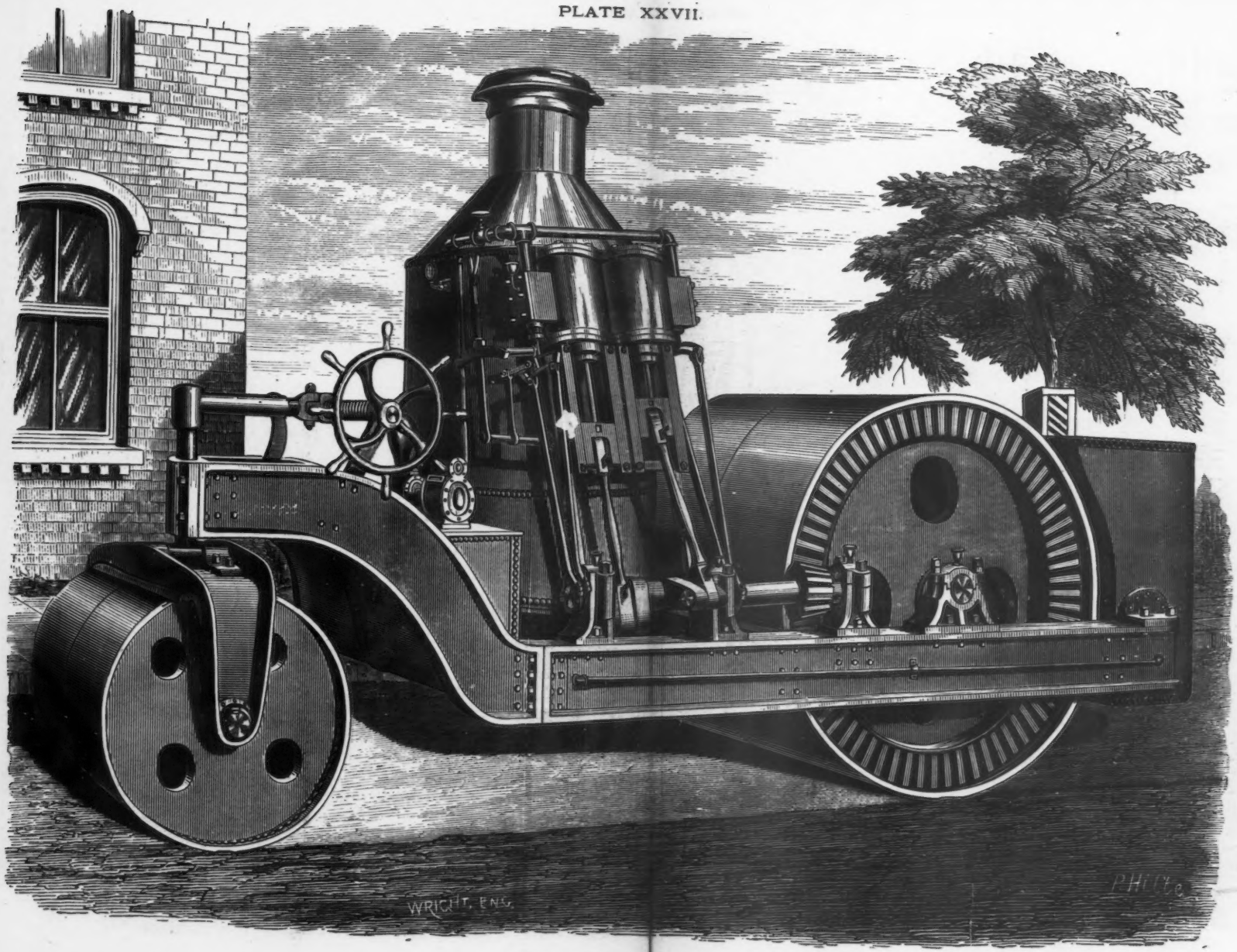
PLATE XXVI.

TRANS. OF AM. SOC. OF CIV. ENGIN'RS.

Vol. VIII.—No. CLXXX.

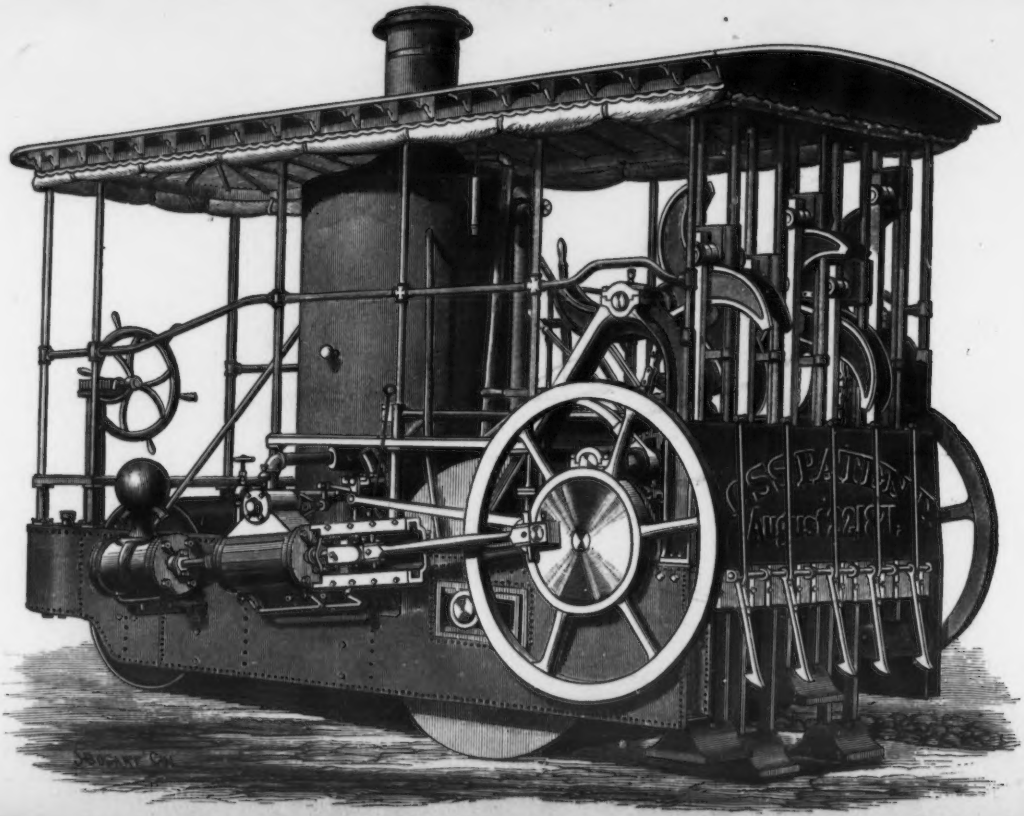
NORTH ON ROADS.

PLATE XXVII.

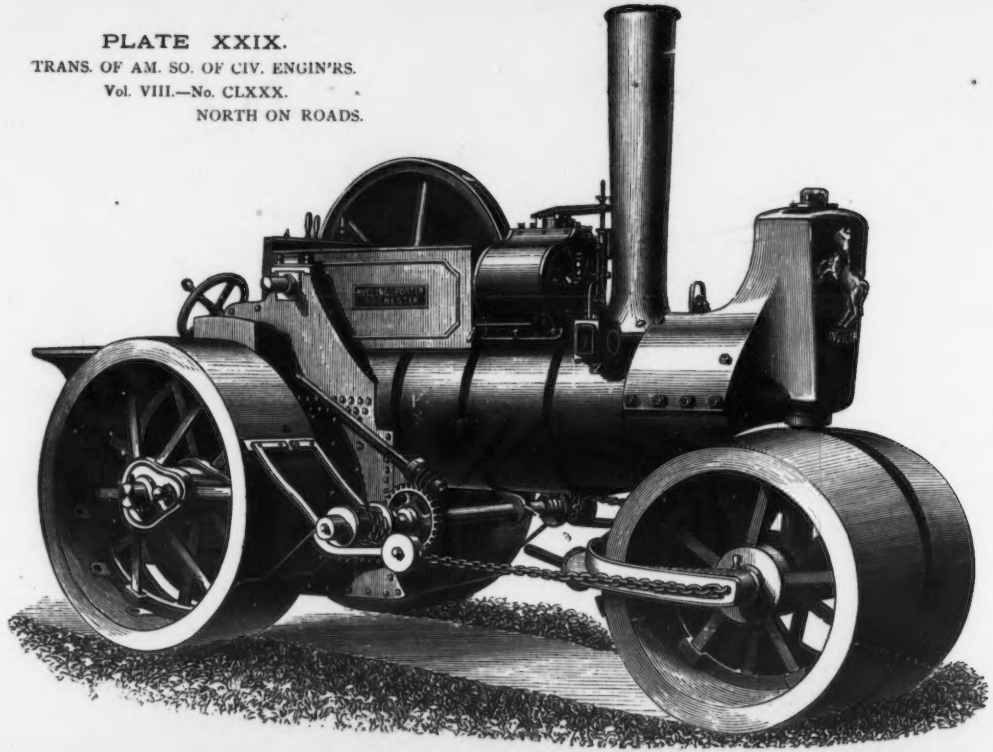


THE LINDELOF ROLLER.

PLATE XXVIII.



THE ROSS ROLLER.



THE AVELING & PORTER ROLLER.

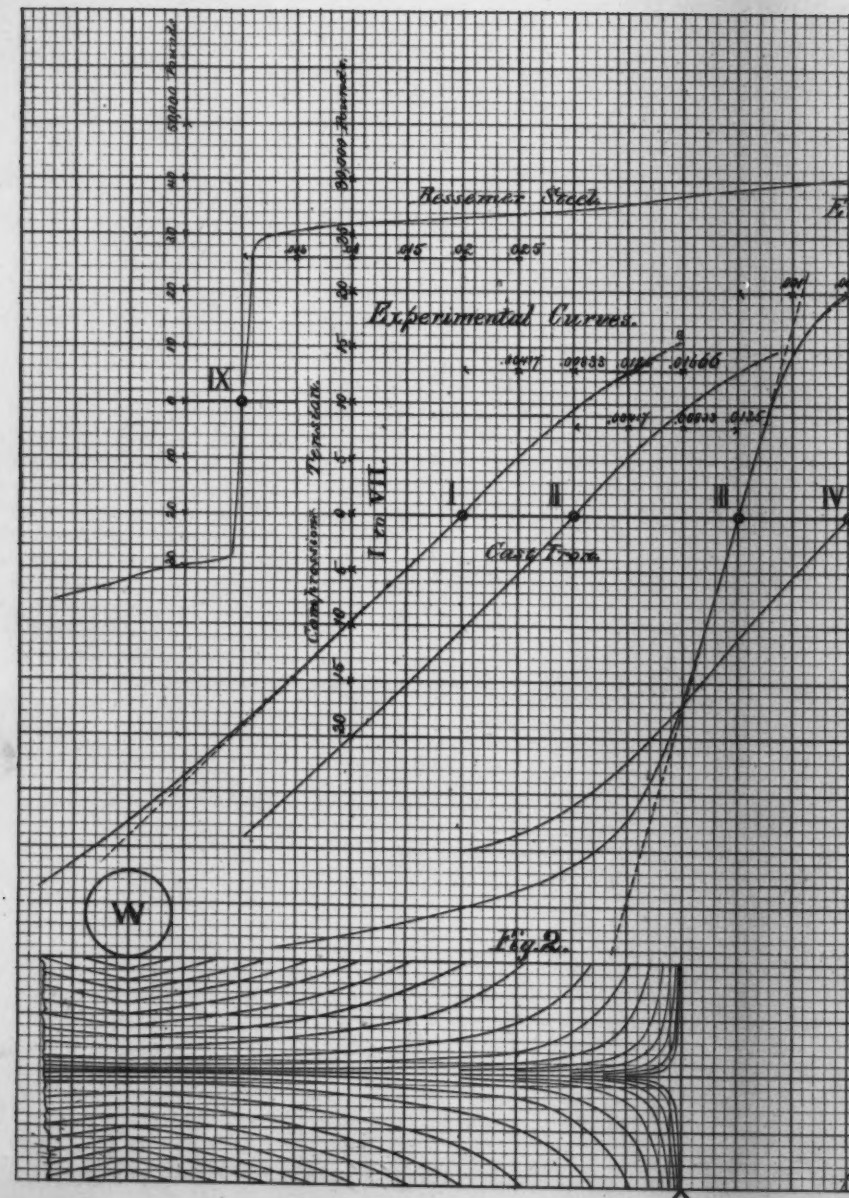

Square Pressure.
Square Pressure.
Bessemer Steel.
Experimental Curves.
IX.
Cast Iron.
I
II
III
IV
W

Fig. 2.

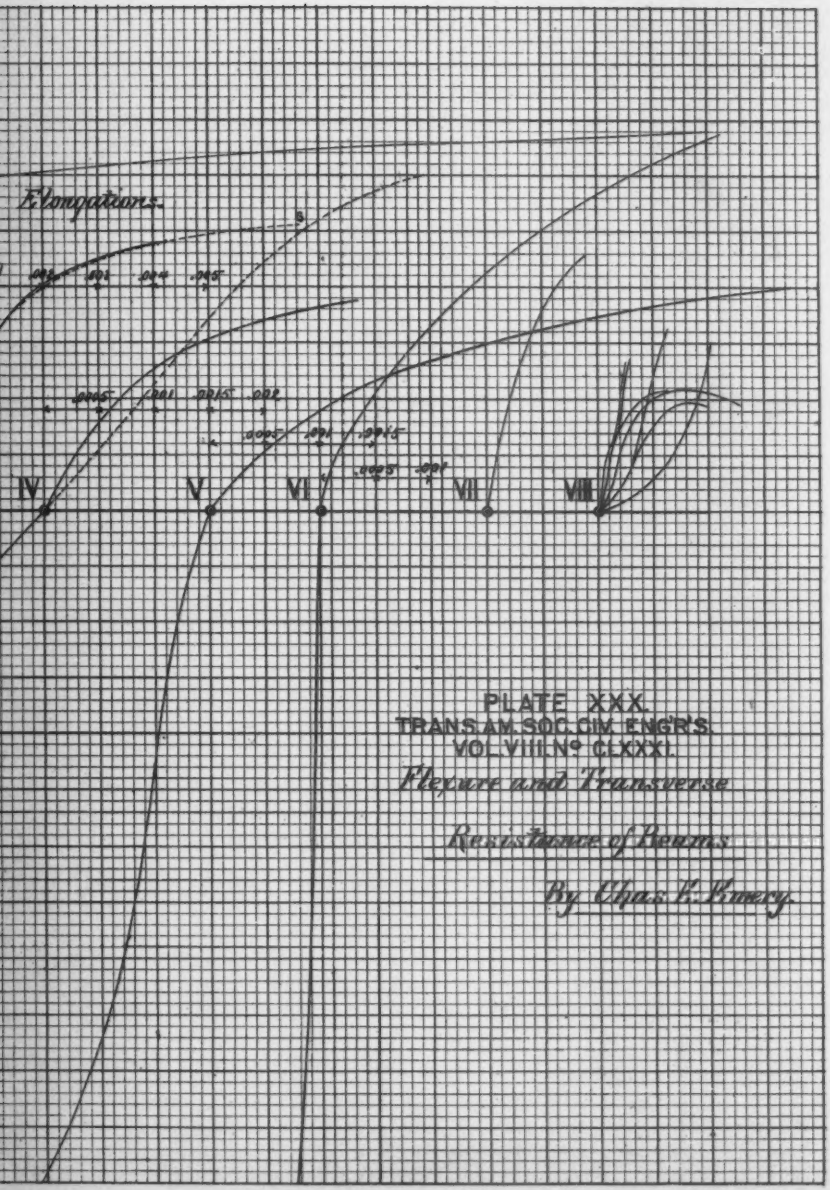


PLATE XXX.
TRANS. AM. SOC. CIV. ENGR'S.
VOL. VIII. No. CLXXXI.

Flexure and Transverse Resistance of Beams

By Chas. E. Emery.

SECTION OF JETTIES.

BETWEEN EAST POINT AND 8000 RESP. 9000 FEET SEAWARD

finished according to Plans

SEE TEXT PAGE 191.

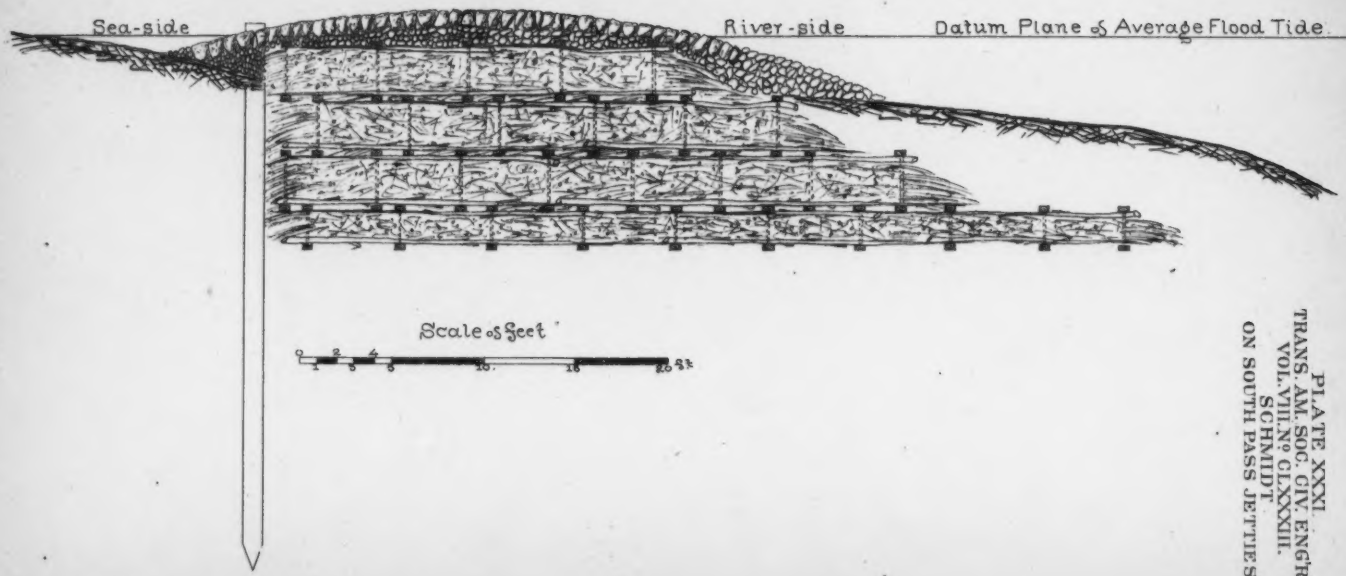


PLATE XXXI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXXIII.
SCHMIDT.
ON SOUTH PASS JETTIES.

SECTIONS

of the lower parts of the jetties, finished according to plans.

SEE TEXT, PAGE 192. 204.

FIG. 1.

SECTION, 9000 FT SEAWARD FROM EASTPOINT.

FIG. 2.

SECTION, 10400 FT SEAWARD FROM EASTPOINT.

FIG. 3.

SECTION, 11800 FT SEAWARD FROM EASTPOINT.

PLATE XXXII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

FIG. 1.

SECTION OF WEST JETTY AS ORIGINALLY
4200 FT SEAWARD FROM EASTPOIN

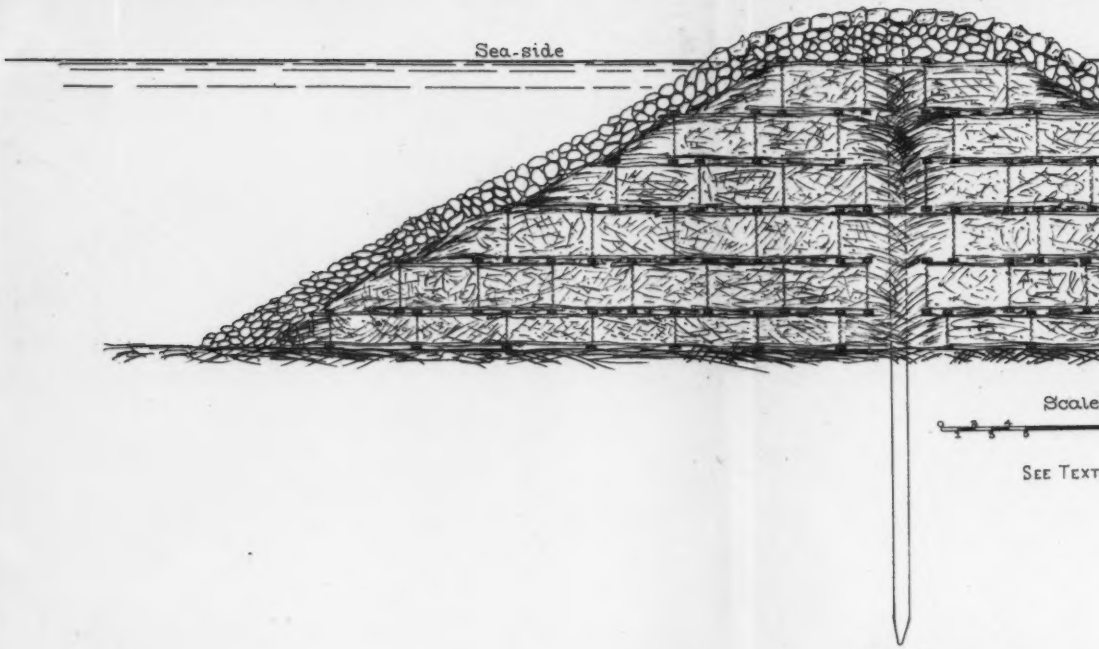
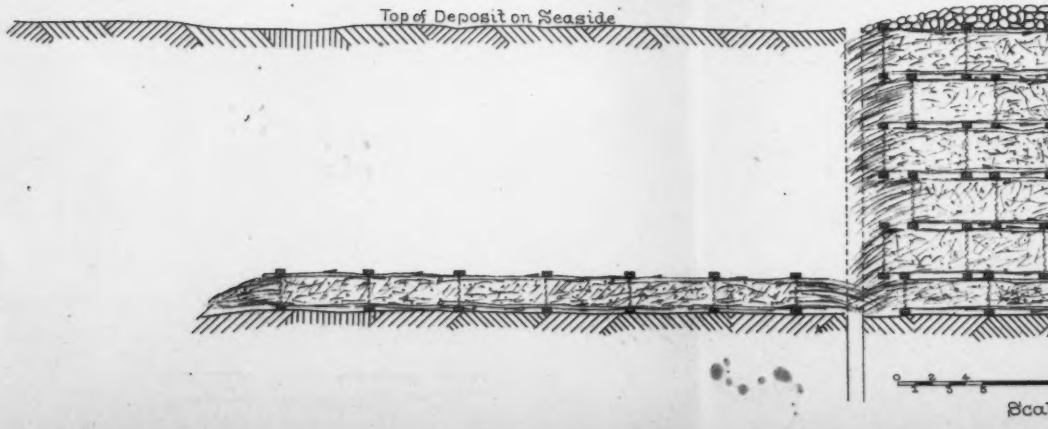


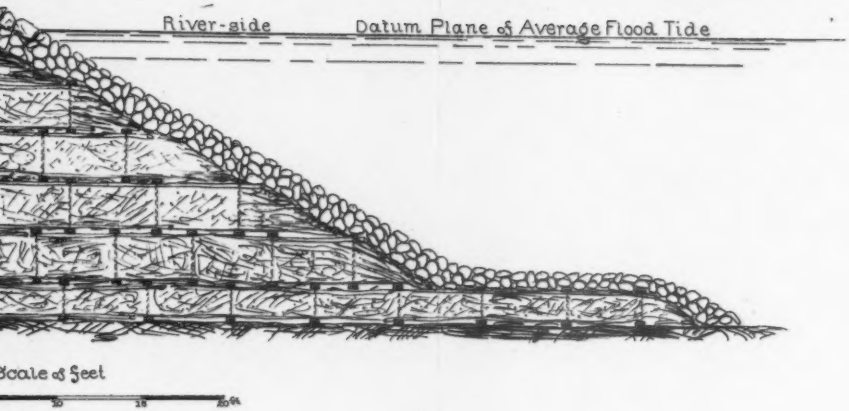
FIG. 2.

SECTION OF WEST JETTY AS CONSTR
4200 FT SEAWARD FROM EASTPOI
SHOWING PROTECTING DEPOSIT ON SEA- AND



LLY PROPOSED
POINT

PLATE XXXIII.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.



TEXT PAGE 195.196.

STRUCTED
POINT
AND RIVERSIDE

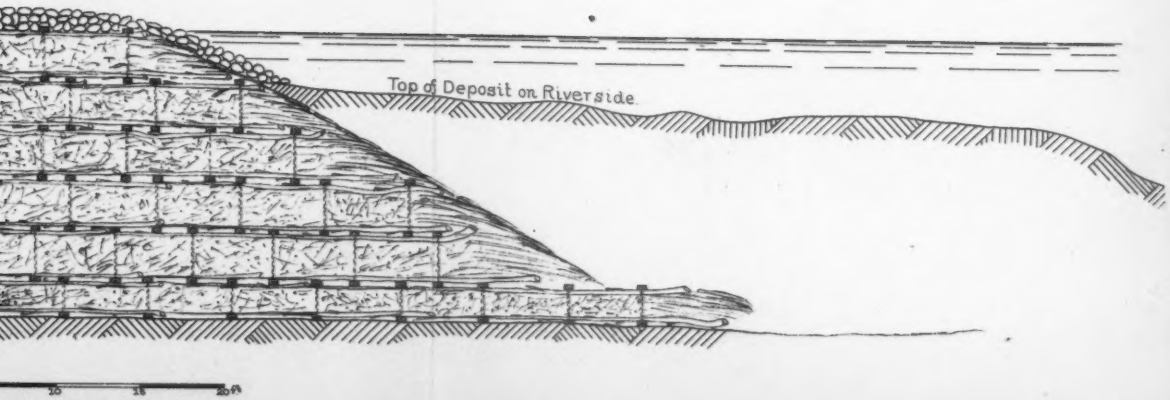


FIG. 1.

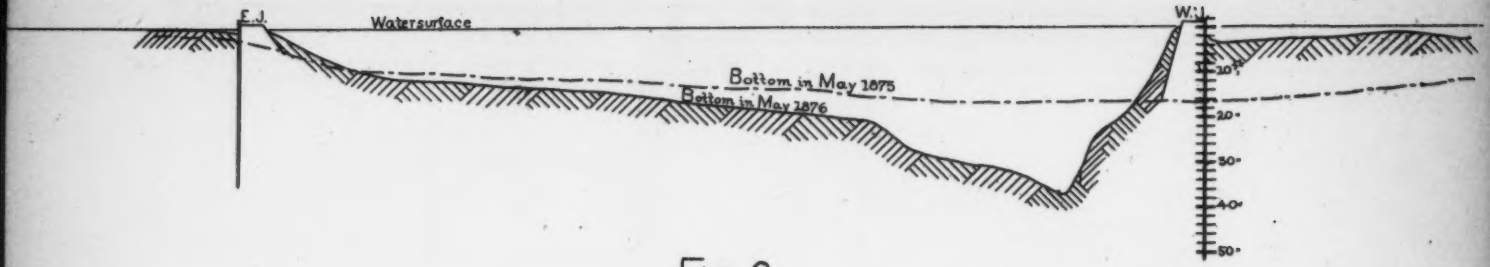
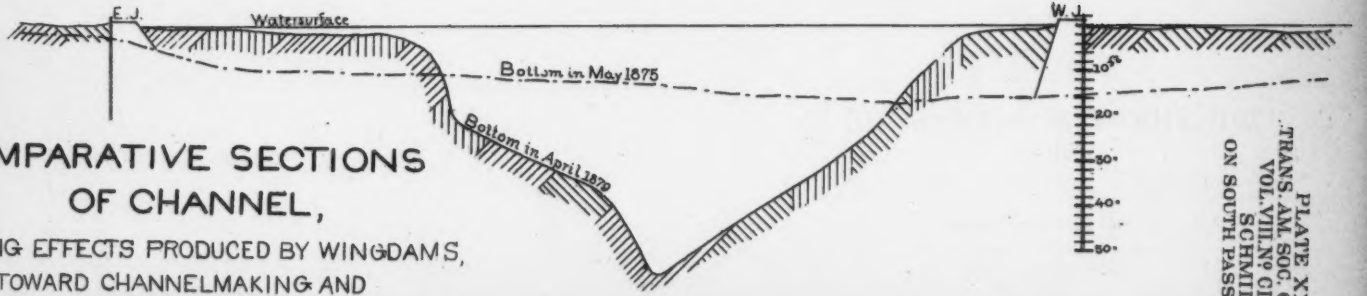


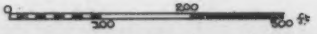
FIG. 2.



COMPARATIVE SECTIONS OF CHANNEL,

SHOWING EFFECTS PRODUCED BY WINGDAMS, TOWARD CHANNELMAKING AND PROTECTION OF JETTIES

SEE TEXT, PAGE 197.



Horizontal Scale of Feet.

PLATE XXXIV.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

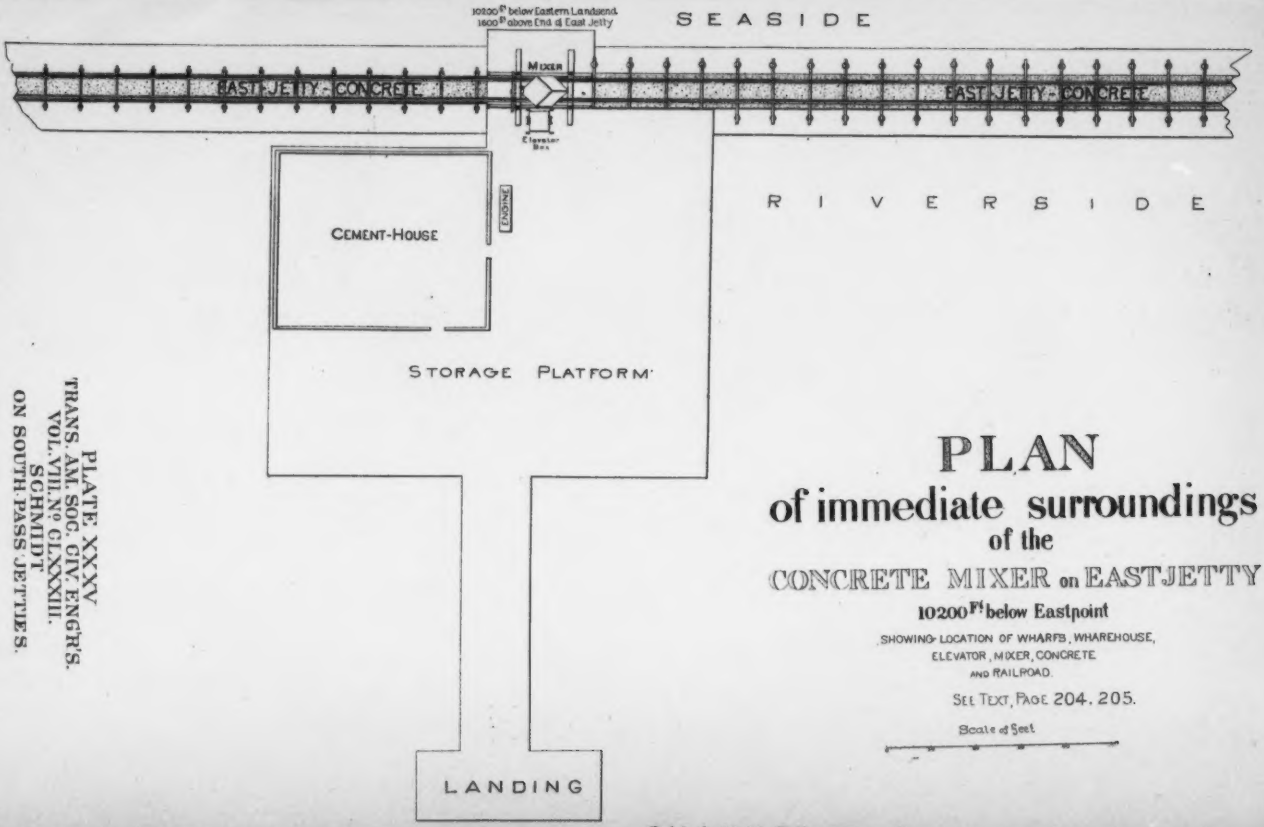


PLATE XXXV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

PLAN
of immediate surroundings
of the
CONCRETE MIXER on EAST JETTY
10200 Ft below Eastpoint

SHOWING LOCATION OF WHARFS, WHAREHOUSE, ELEVATOR, MIXER, CONCRETE AND RAILROAD.

SEE TEXT, PAGE 204. 205.

Scale of Feet

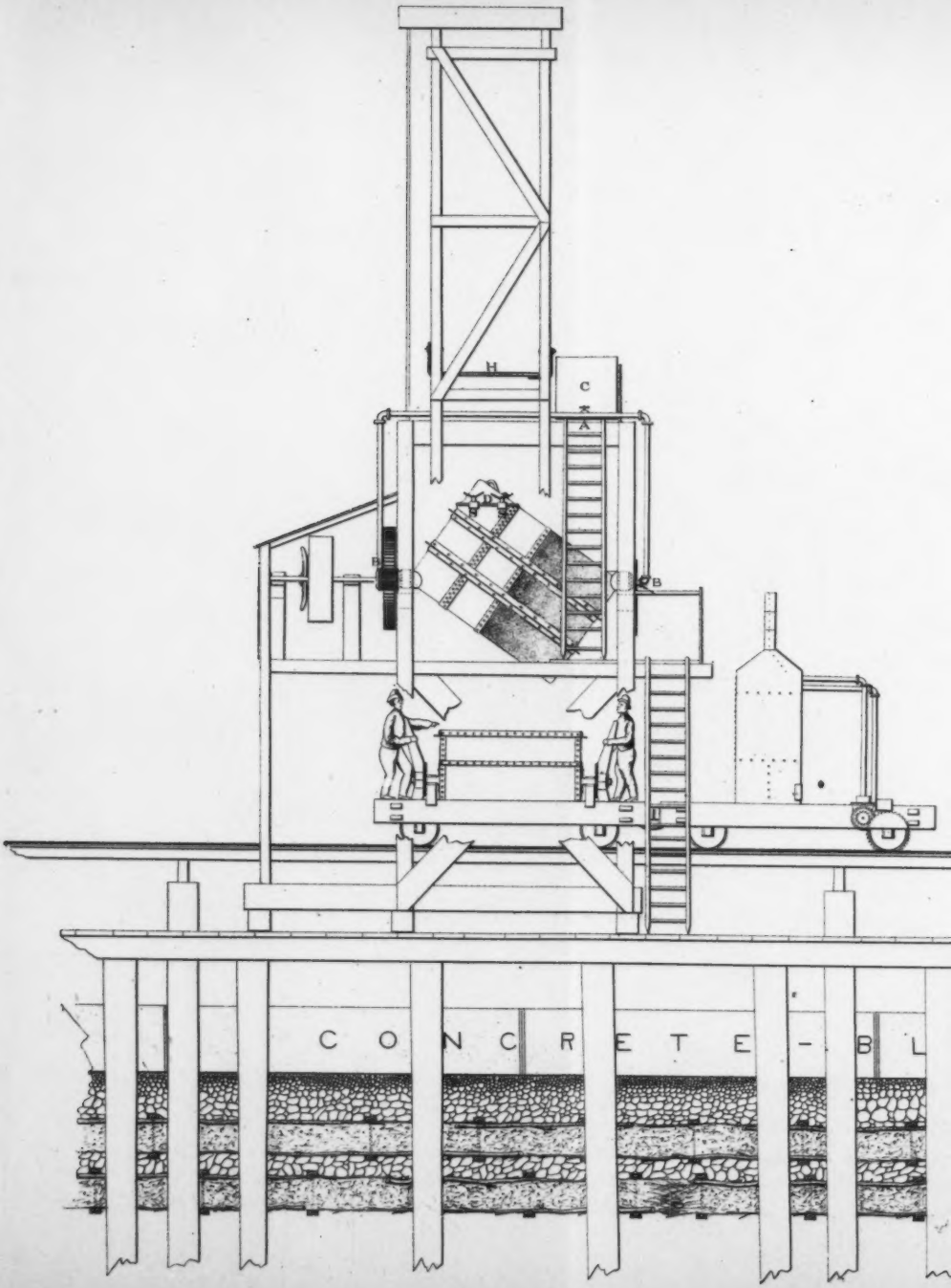

C O N C R E T E - B L

PLATE XXXVI.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

CONCRETE MIXER on EASTJETTY

10200 Ft below Eastpoint

SEE TEXT, PAGE 205.207.

SIDE ELEVATION

LOOKING EAST

Scale of Feet

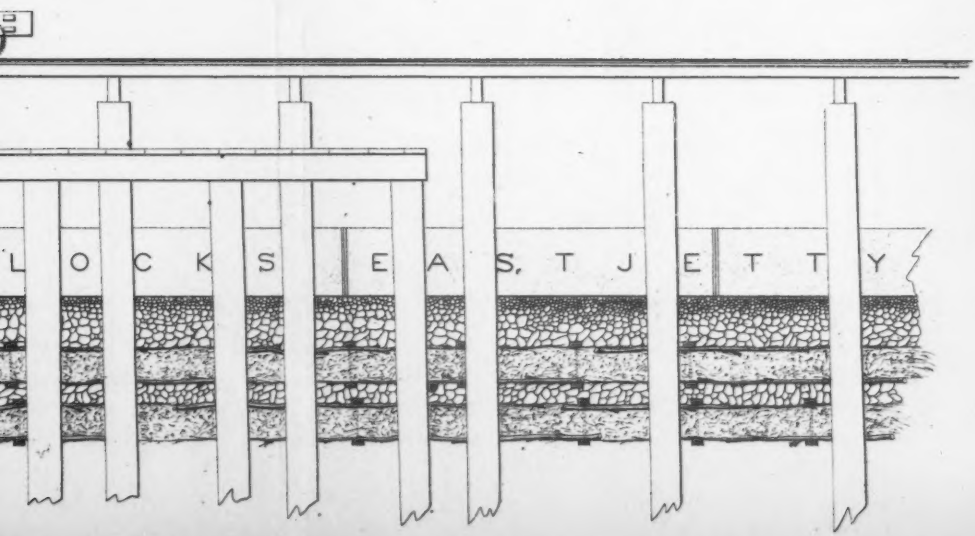


PLATE XXXVII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

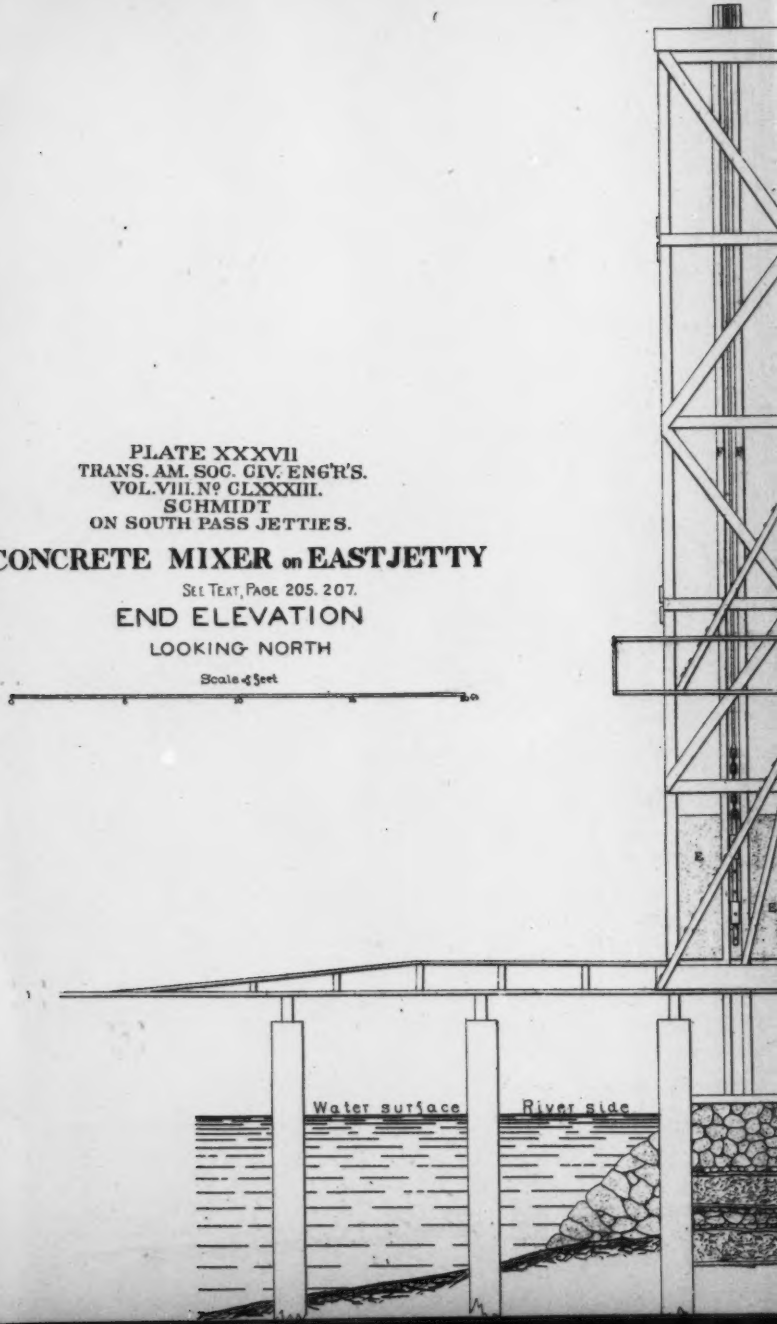
CONCRETE MIXER on EAST JETTY

SEE TEXT, PAGE 205. 207.

END ELEVATION

LOOKING NORTH

Scale of Feet



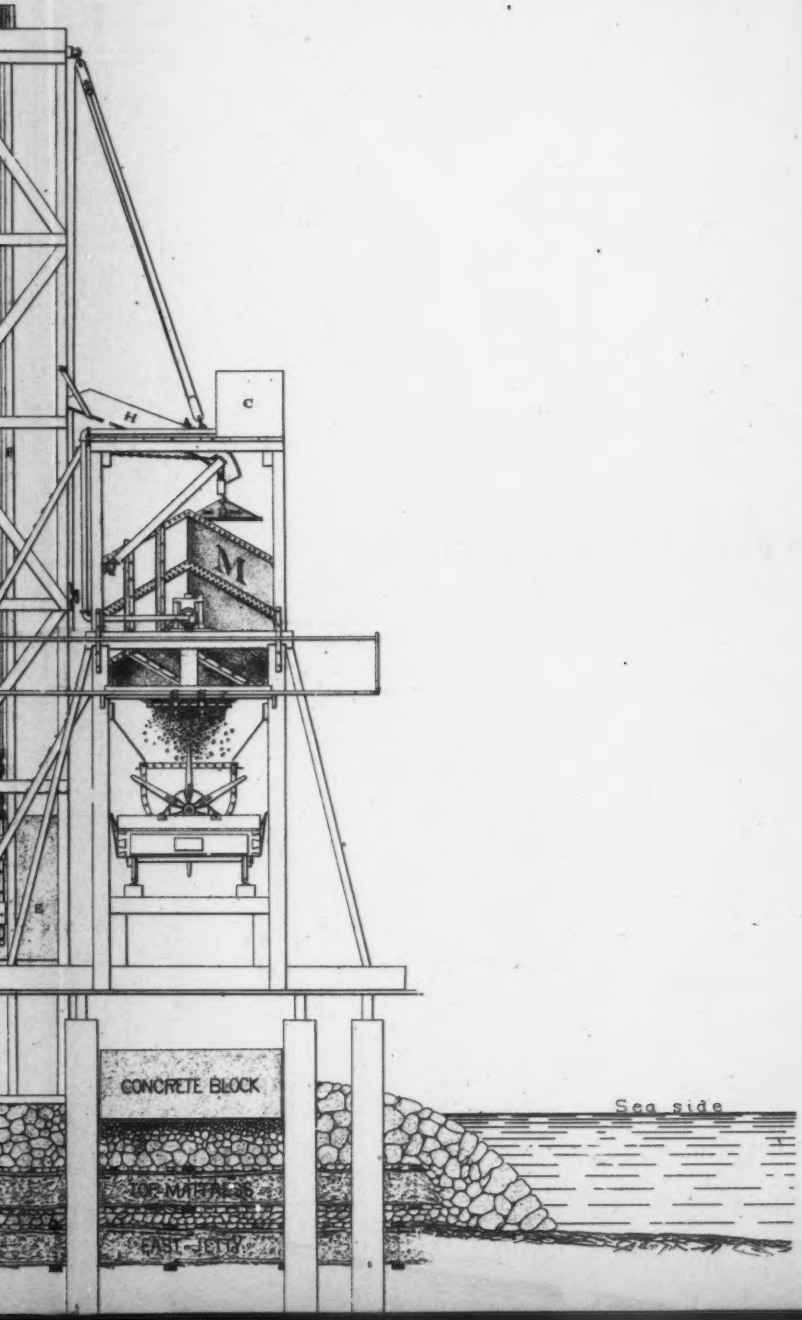

H
C
M
CONCRETE BLOCK
Sea side

FIG. 2.

MOULD BOX FOR CONCRETE BLOCKS
END ELEVATION

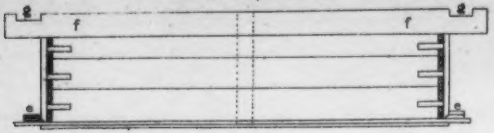


FIG. 3.

MOULD BOX FOR CONCRETE BLOCKS
SECTION ON M-N

PLATE XXXVIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. № CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

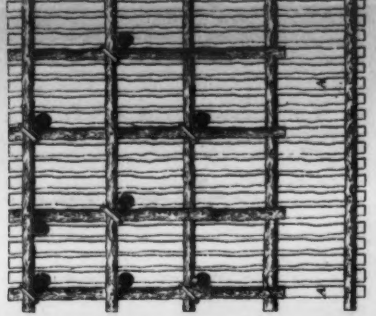
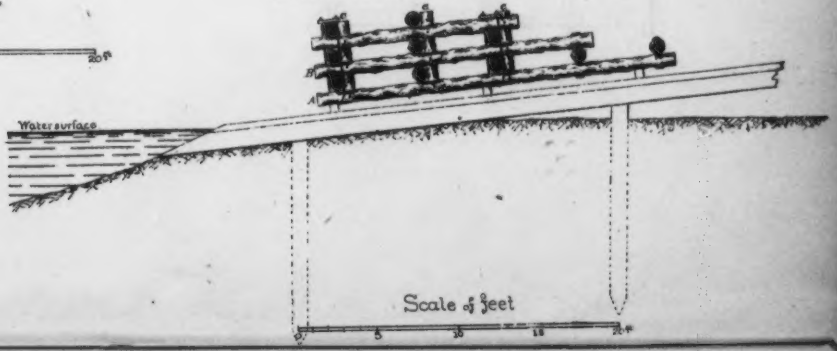


FIG. 5.

PALMETTO-CRIB-WORK
END ELEVATION,
SHOWING POSITION ON WAYS



SEE TEXT, PAGE 208. 211. 216. FIG. 1.

MOULD BOX FOR CONCRETE BLOCKS

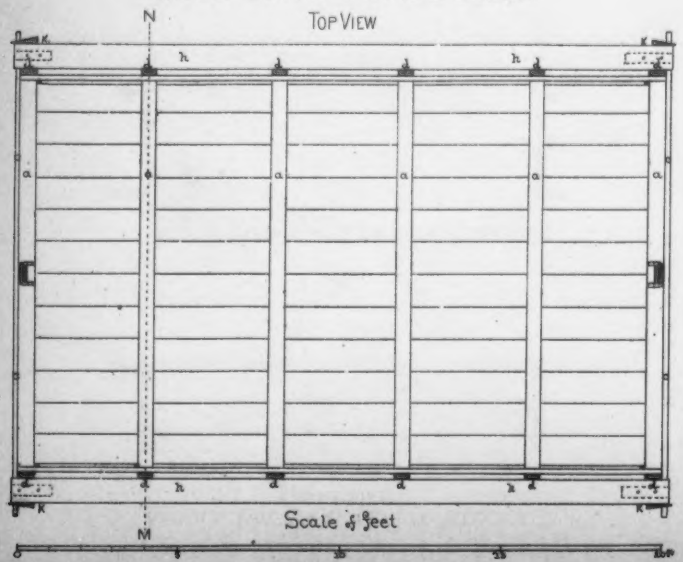
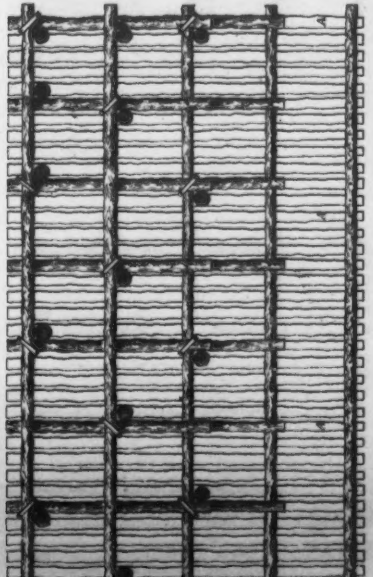


FIG. 2.

FIG. 4.

PALMETTO-CRIB-WORK

TOP VIEW



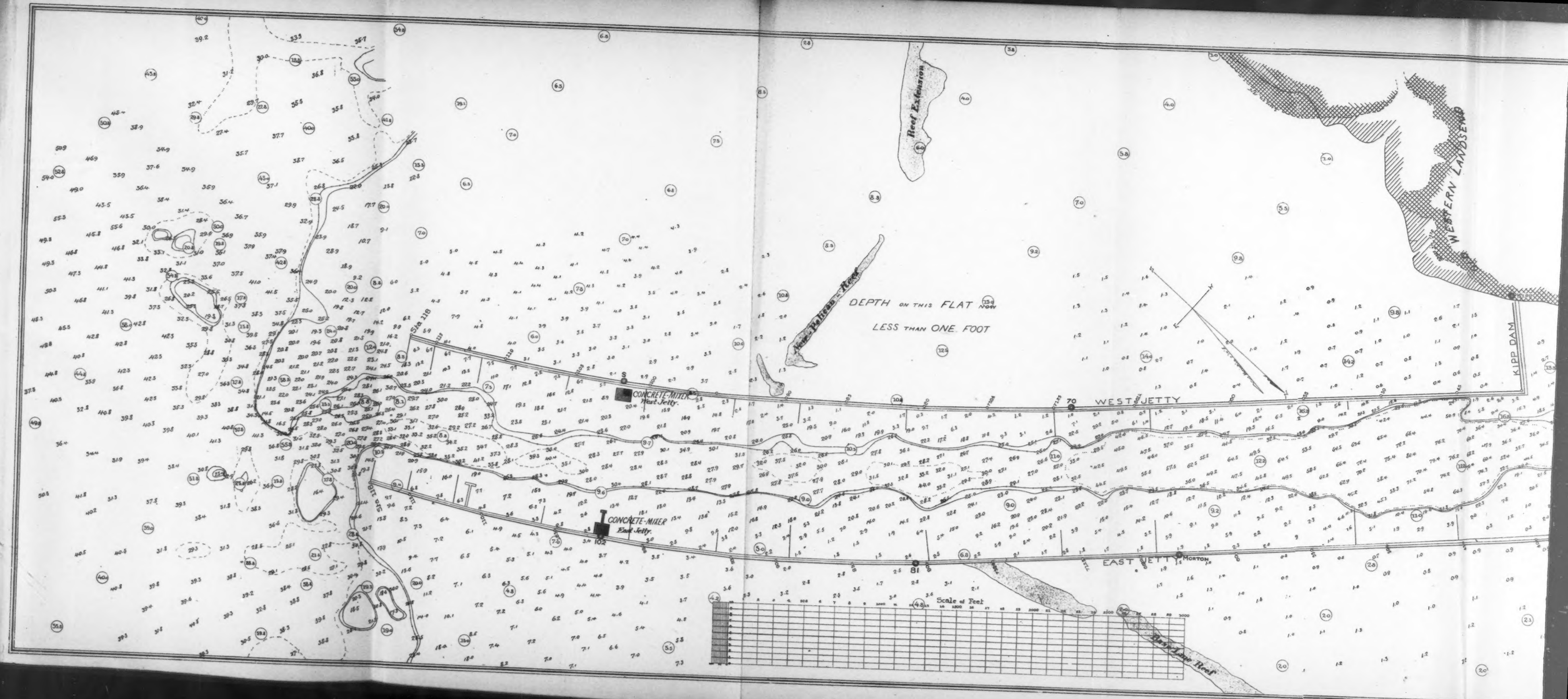

Reef Extension
WESTERN LANDSEND
KIPP DAM
New Pelican Reef
DEPTH ON THIS FLAT 13d NOW
LESS THAN ONE FOOT
Sta 118
CONCRETE-MITER
Head Jetty.
70 WEST JETTY
Sta 110
CONCRETE-MITER
East Jetty.
102
81
EAST JETTY
MORTON
Scale of Feet
New Lake Reef

CHART
OF THE
SOUTH PASS JETTIES
OF THE
MISSISSIPPI RIVER
SHOWING THE
POSITION OF THE WORKS AND THE
CHANGES from MAY 1875, to APRIL 1879

NOTE Soundings are expressed in feet and tenths, and refer to the plane of Average Flood Tide of the U.S. Engineers. Soundings enclosed in circles denote the depths in May 1875, all others the depths in April 1879.

PLATE XXXIX
TRANS. AM. SOC. CIV. ENG'R'S,
VOL. VIII. Nº CLXXXIII
SCHMIDT
ON SOUTH PASS JETTIES.

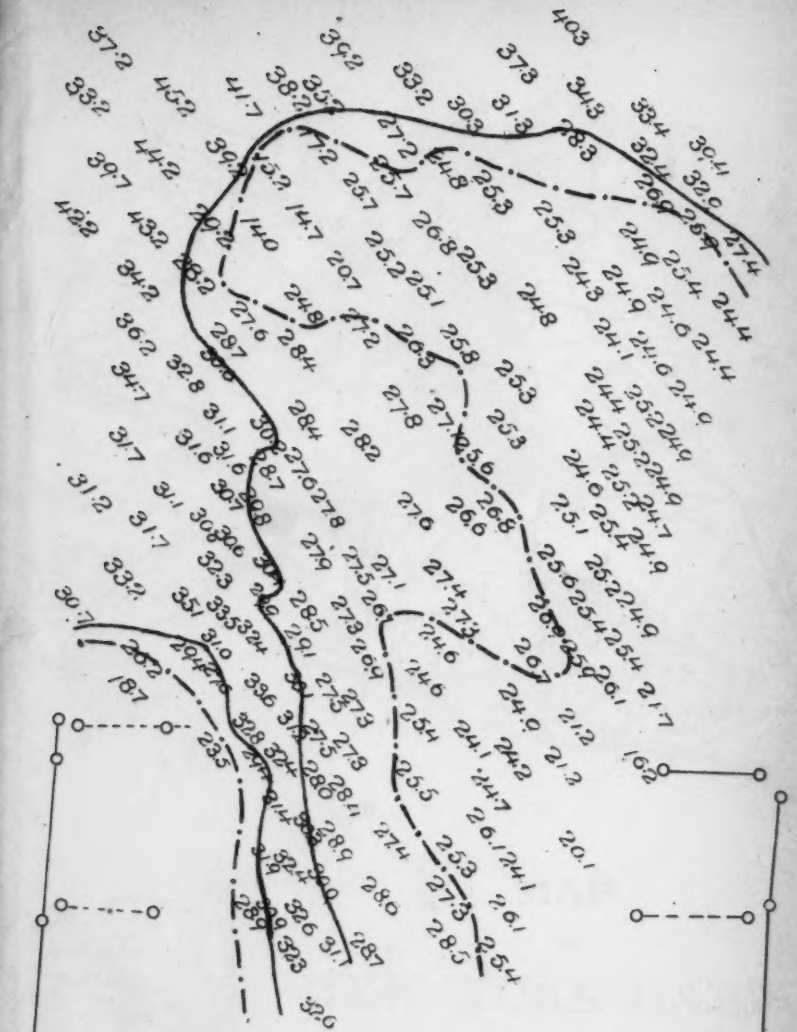
SEE TEXT PAGE 189. 197. 217.

CONTOURS
25 Feet APRIL 1879
26 " " "
30 " " "

WESTERN LANDSEND
KIPP DAM
WEST JETTY
EAST JETTY
HORTON
SOUTH PASS
LIGHT-HOUSE
EASTERN LANDSEND
OLD CHANNEL
Pass Jetty Roof

SOUTH
CHART
OF THE
HEAD OF THE PASSES
OF THE
MISSISSIPPI RIVER
SHOWING THE
POSITION OF THE WORKS AND THE
CHANGES from MAY. 1875, to JUNE 10TH 1879
Notes.
The black areas express shoals. The amount is entered in feet and tenth of feet.
The dotted line of the shoalest areas denotes the neutral point where no scour and no deposit has occurred.
The darker shaded areas denote deposit. The gradations is expressed by contours shewn at 5, 10, 15, 20, 25, 30 and 35 feet of deposit.

PLATE XL
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.



SOUTH PASS BAR
SOUNDINGS BY U.S. ENGINEERS
JULY, 8. 1879
REDUCED TO AVERAGE FLOOD TIDE
SHOWING A CHANNEL 30 FEET DEEP THROUGH THE BAR
SEE TEXT PAGE 226.

CONTOURS
26 FEET DEEP
30 " "

PLATE XLI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES.

MAP

OF

NEW YORK HARBOR

Scale of Miles.

PLATE XLII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIV.
MACDONALD
ON OCEAN PIER AT CONEY ISLAND.

FIG. 1.

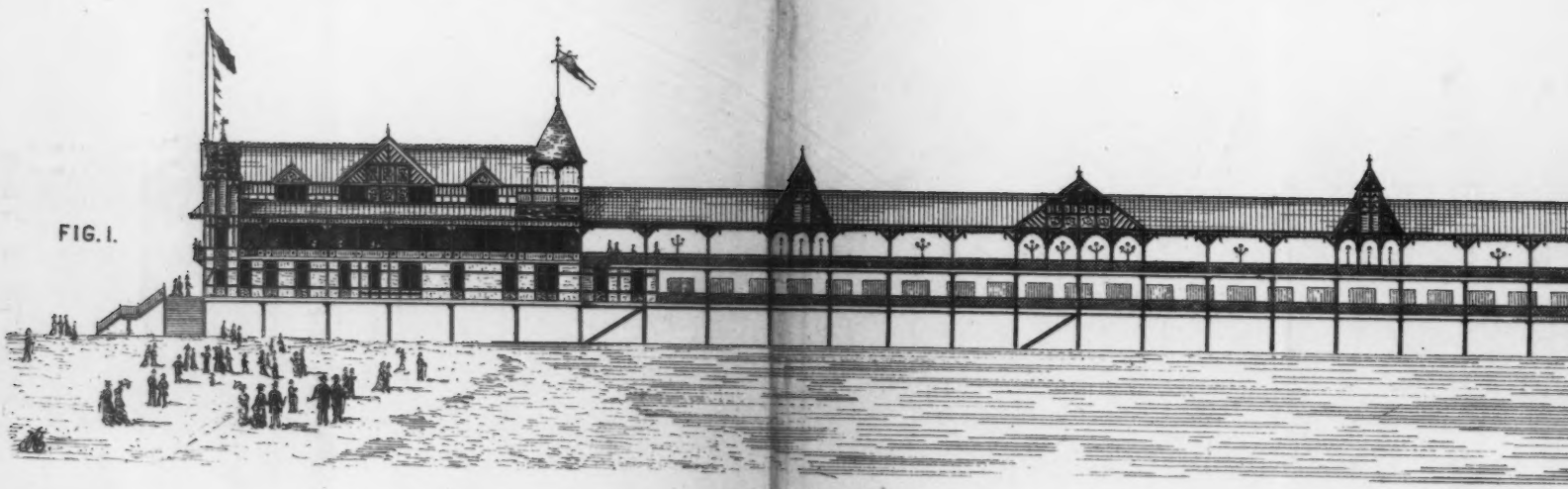
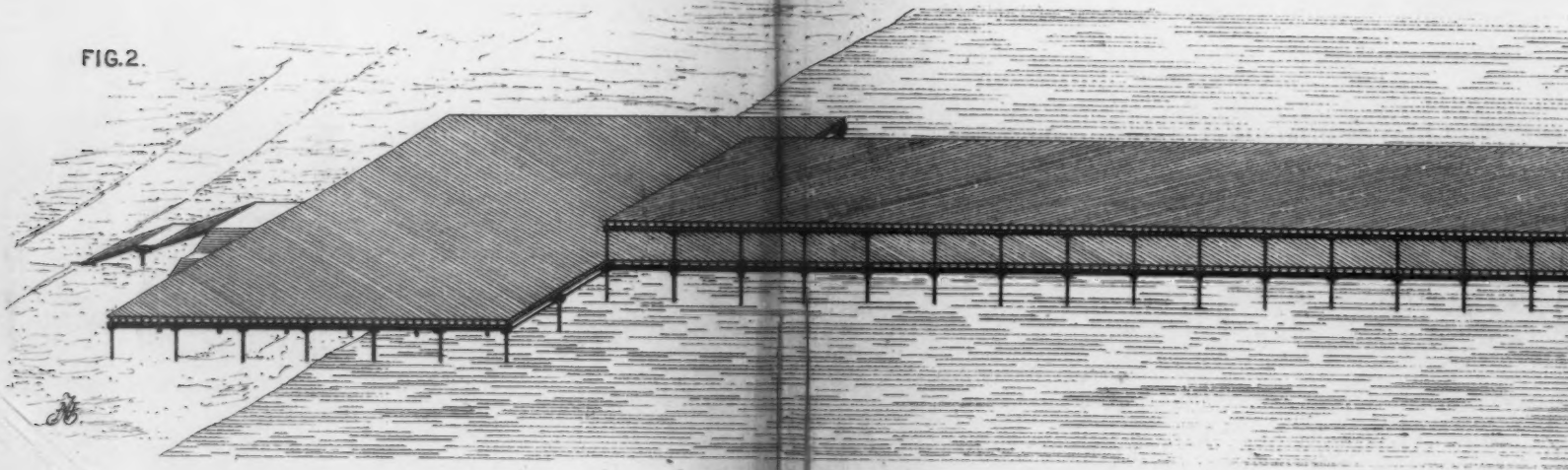
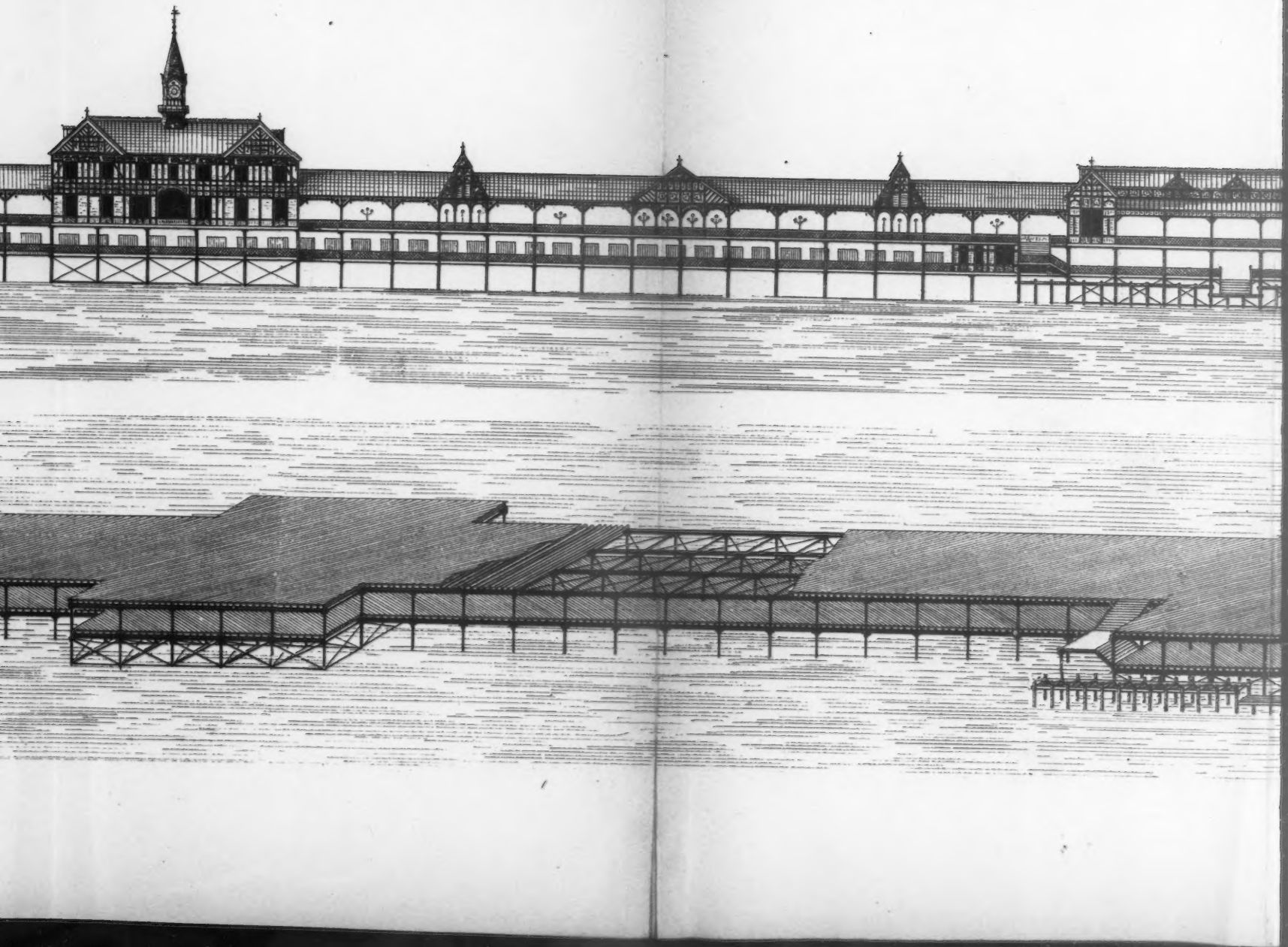
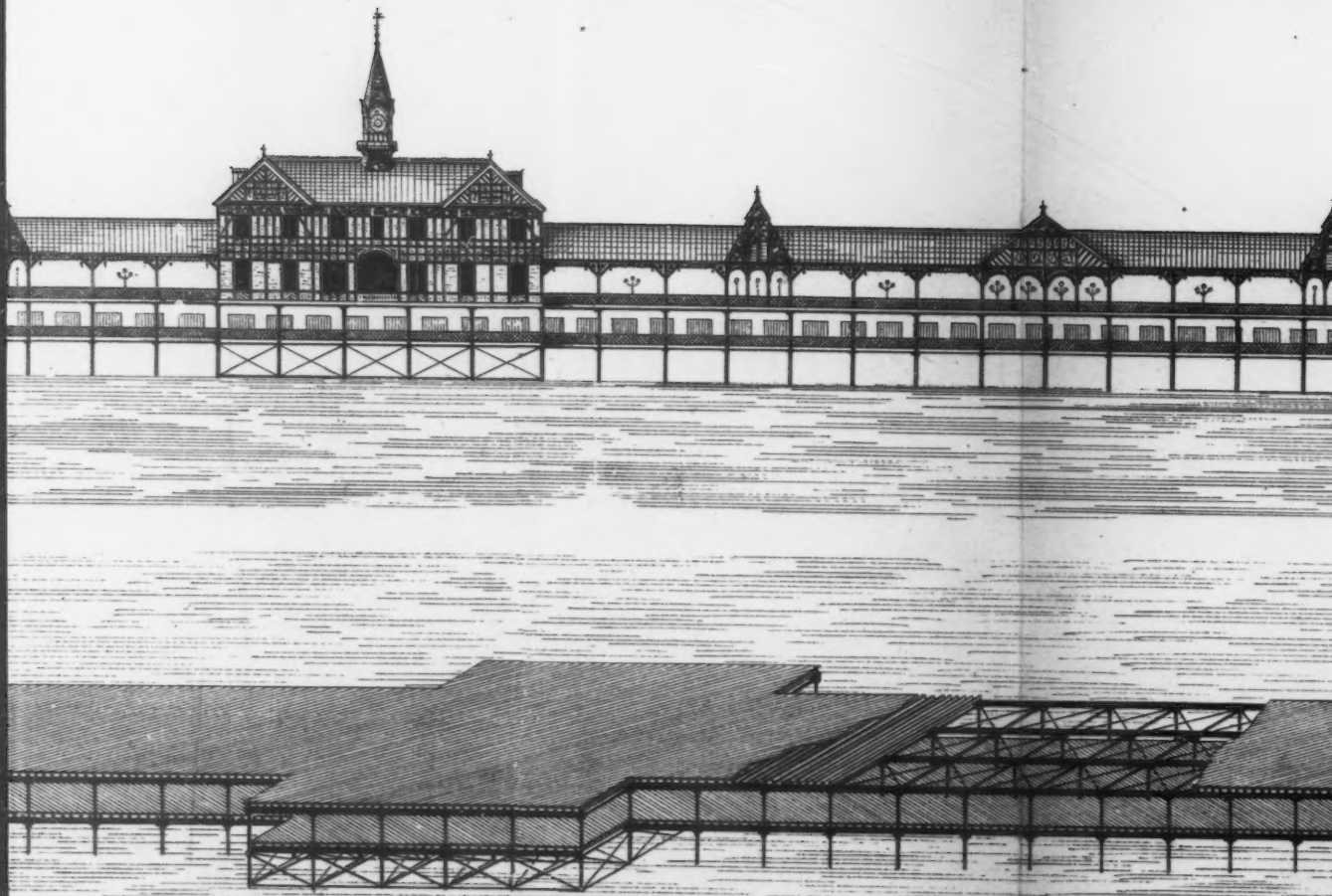


FIG. 2.







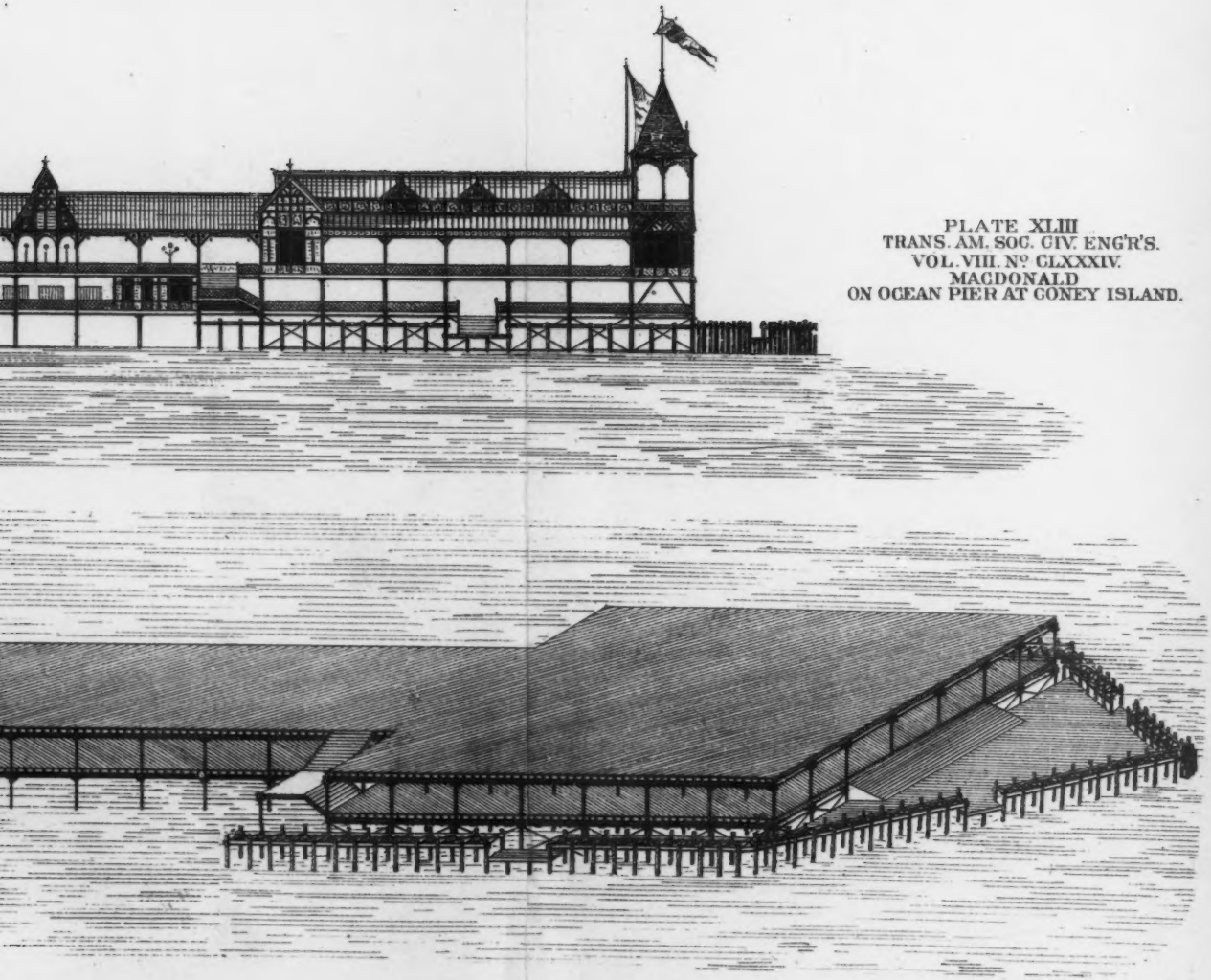
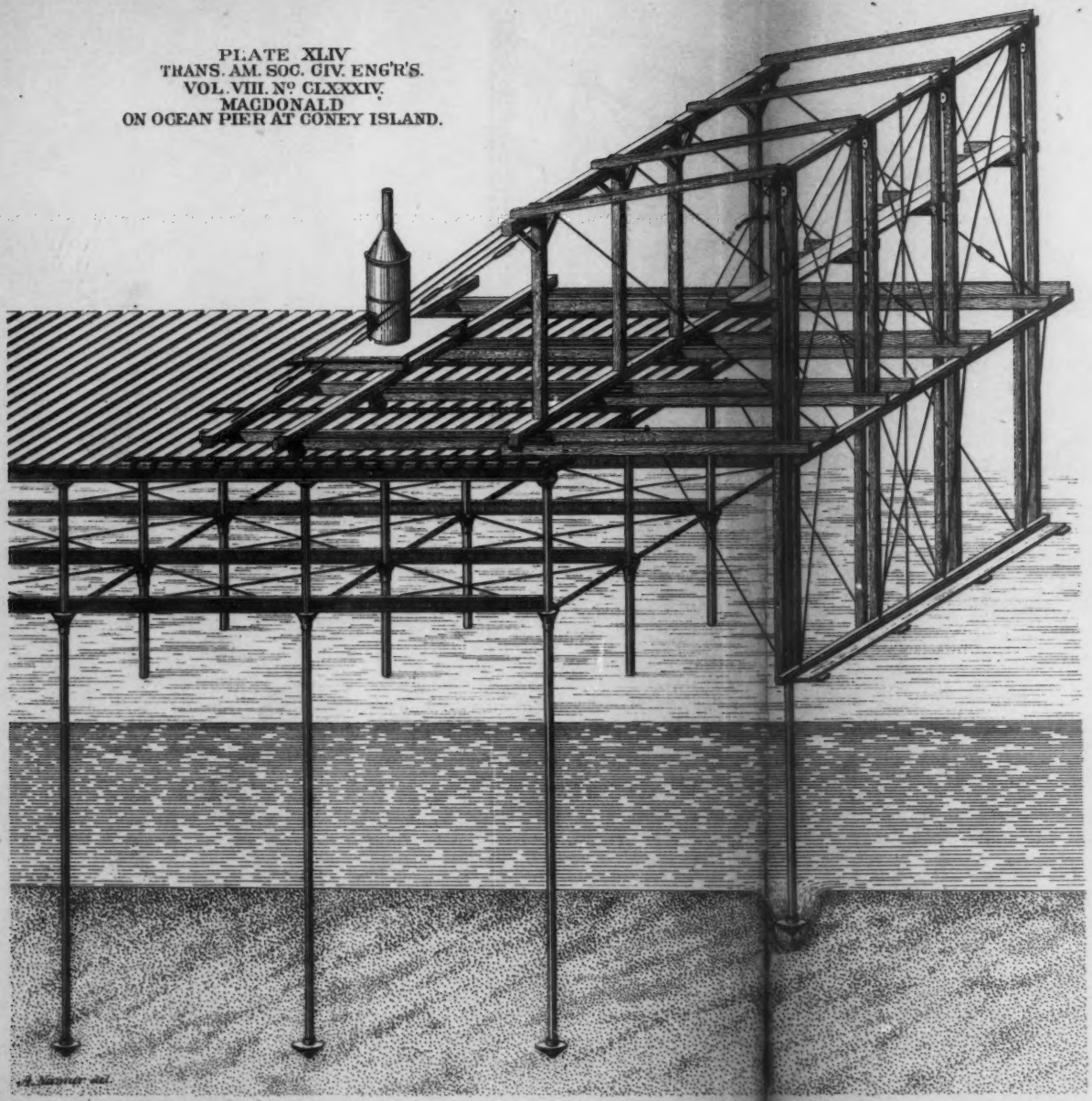


PLATE XLIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIV.
MACDONALD
ON OCEAN PIER AT CONEY ISLAND.

PLATE XLIV
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXIV.
MACDONALD
ON OCEAN PIER AT CONEY ISLAND.



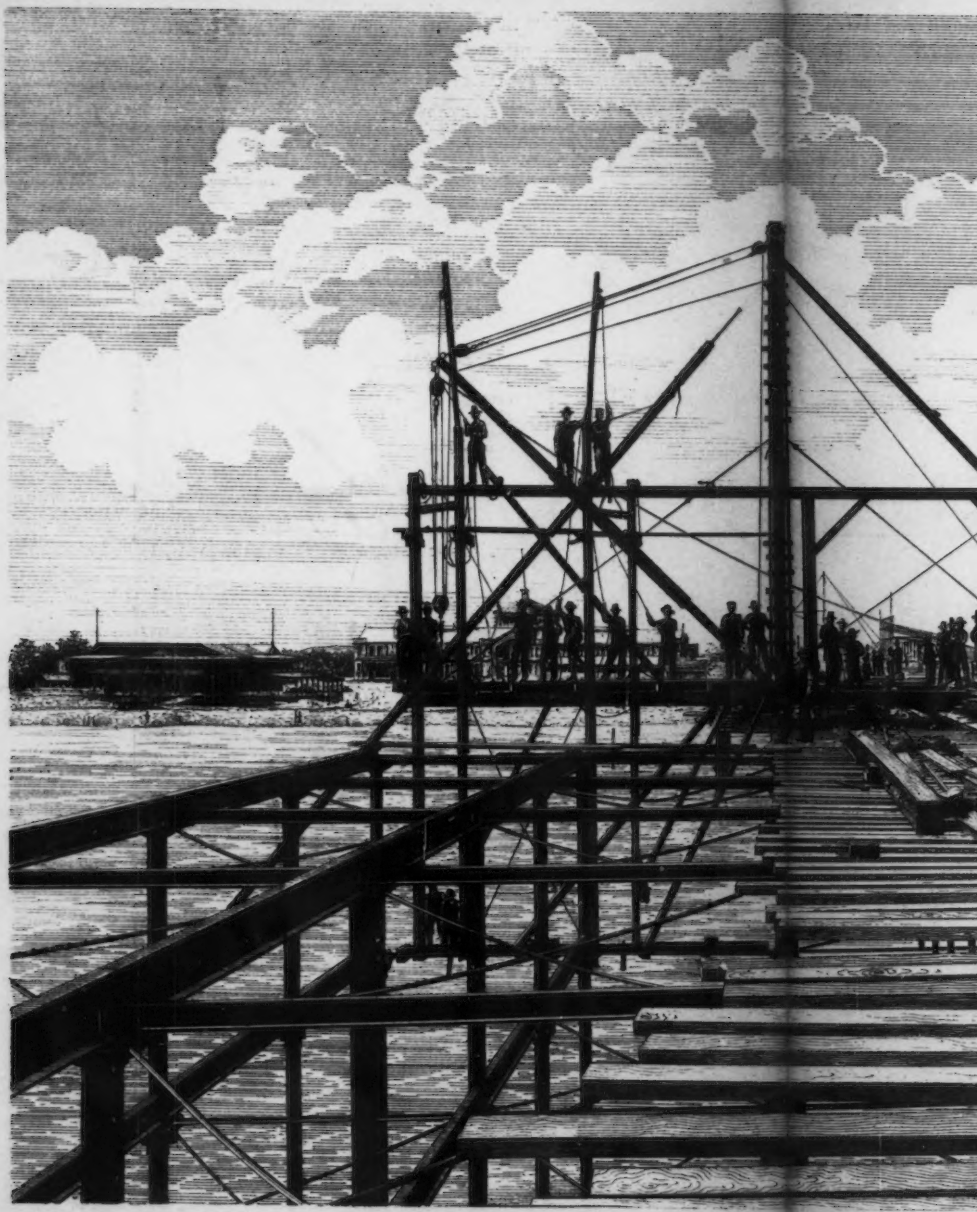
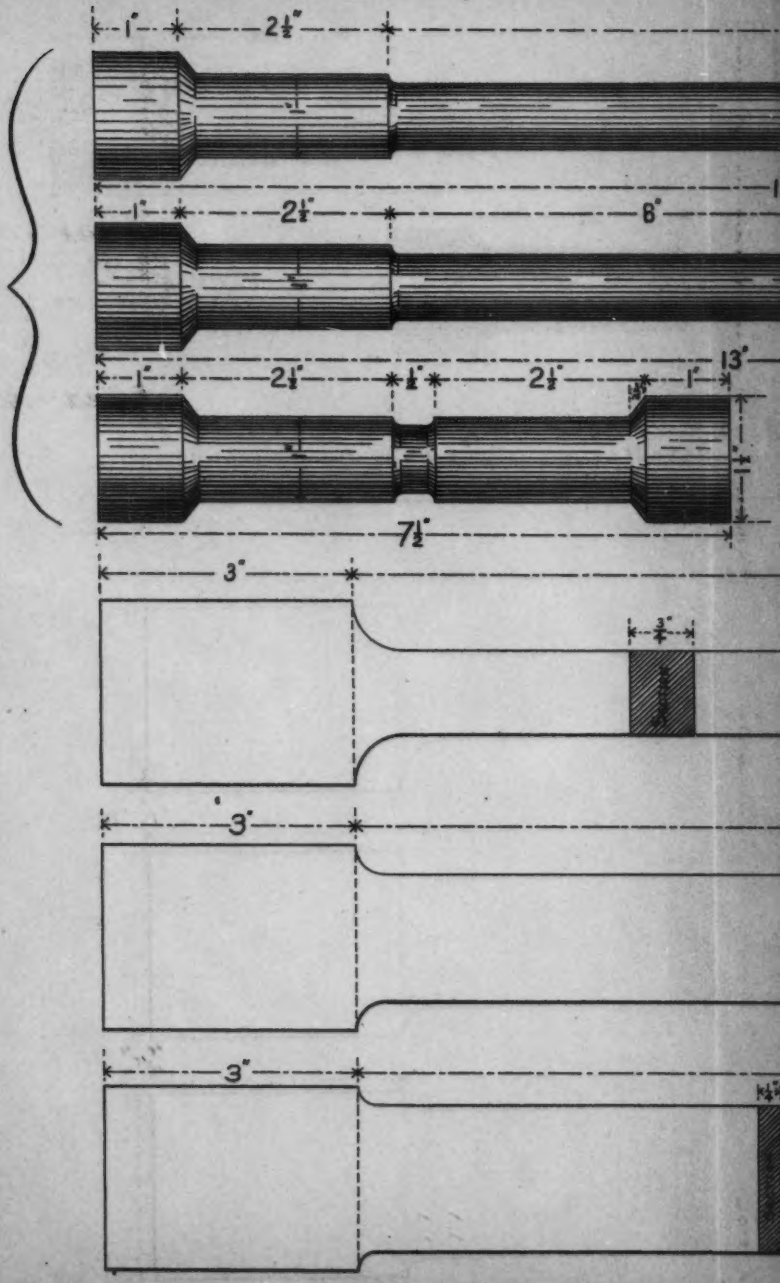


PLATE XIV.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXXIV.
MACDONALD
ON OCEAN PIER AT CONEY ISLAND.

PLATE XLVI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. VIII. No. CLXXXIV.
MACDONALD
ON OCEAN PIER AT CONEY ISLAND.

N.Y.L

SAMPLE BARS OF WROUGHT IRON



Y. L. E. & W. R. R.

ON FOR TESTS OF TENSILE STRENGTH

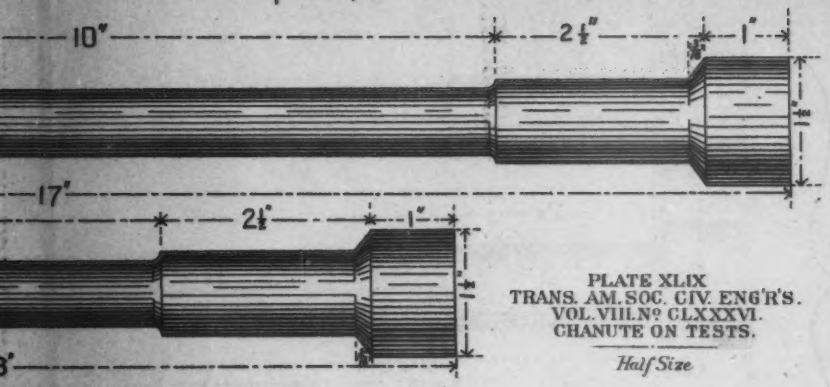
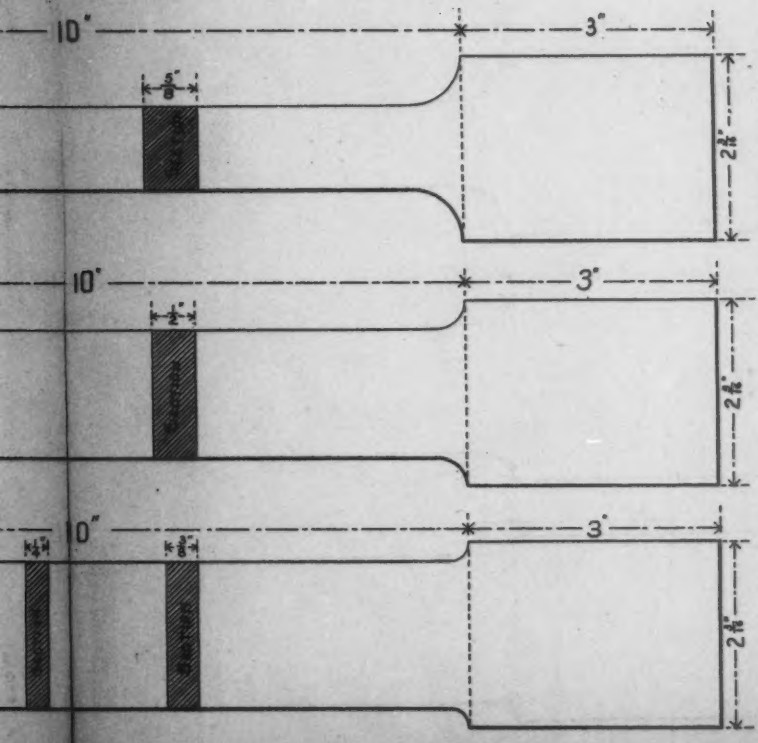


PLATE XLIX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXVI.
CHANUTE ON TESTS.

Half Size

—N.B.—
—AREA OF REDUCED SECTION ONE HALF SQUARE INCH—
—DIAMETER = 0.7978 INCH—



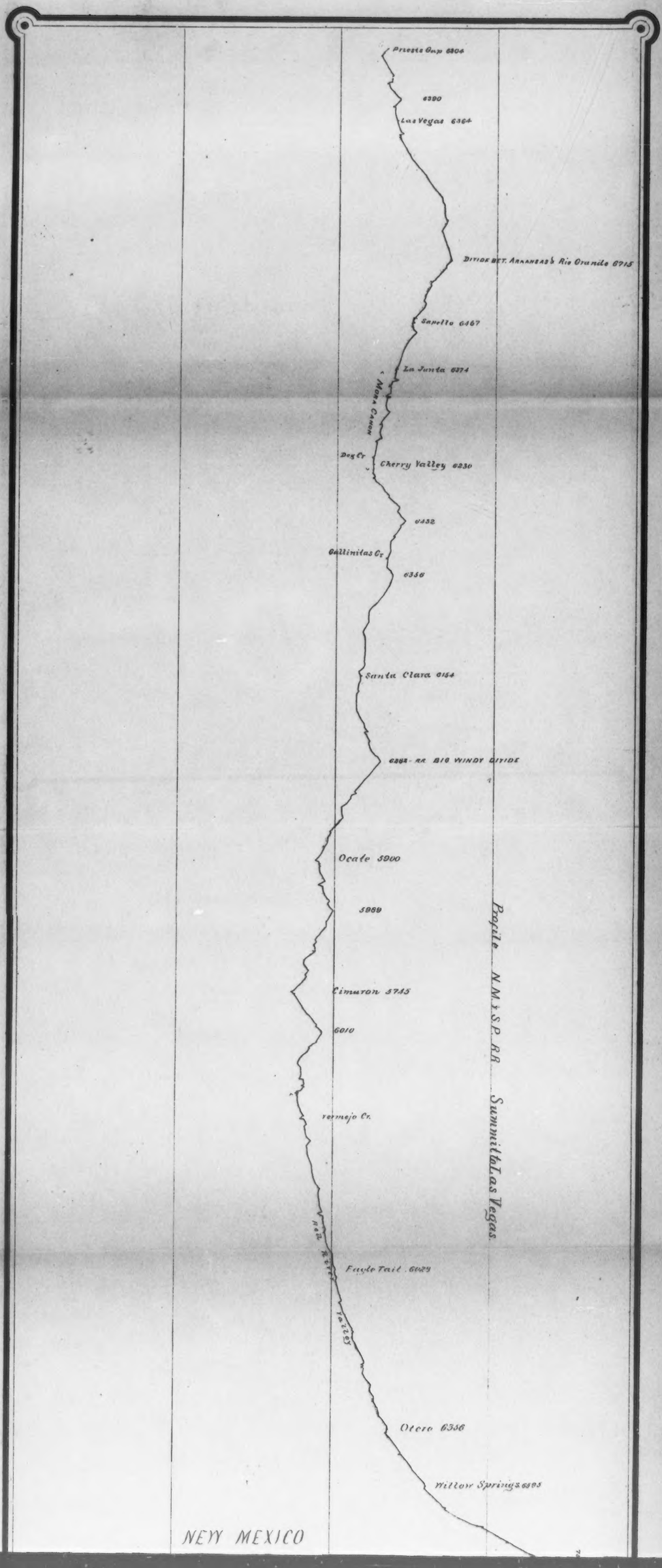

Pecos Gap 6804
6390
Las Vegas 6364
Divide Bet. Arkansas & Rio Grande 6715
Sapello 6467
La Junta 6374
Mora Canon
Dog Cr
Cherry Valley 6230
6432
Gallinitas Cr
6356
Santa Clara 6154
6282 - AA. BIG WINDY DIVIDE
Ocate 5900
5989
Cimaron 5745
6010
vermejo Cr.
near Raton
Foyle Tail. 6029
Pass
Otero 6356
Willow Springs 6393
Pecos N.M.S.P.R.R. Summit to Las Vegas
NEW MEXICO

PLATE I.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII. Nº CLXXVII.
BURR ON RAILROAD OVER RATON MTS

PROFILE
of the
PUEBLO & ARKANSAS VALLEY
and
NEW MEXICO & SOUTHERN PACIFIC
RAIL ROADS
from
LA JUNTA COLORADO
to
LAS VEGAS NEW MEXICO

A.A. ROBINSON, CHIEF ENG'R.
J.D. BURR, ASSIST. ENG'R.

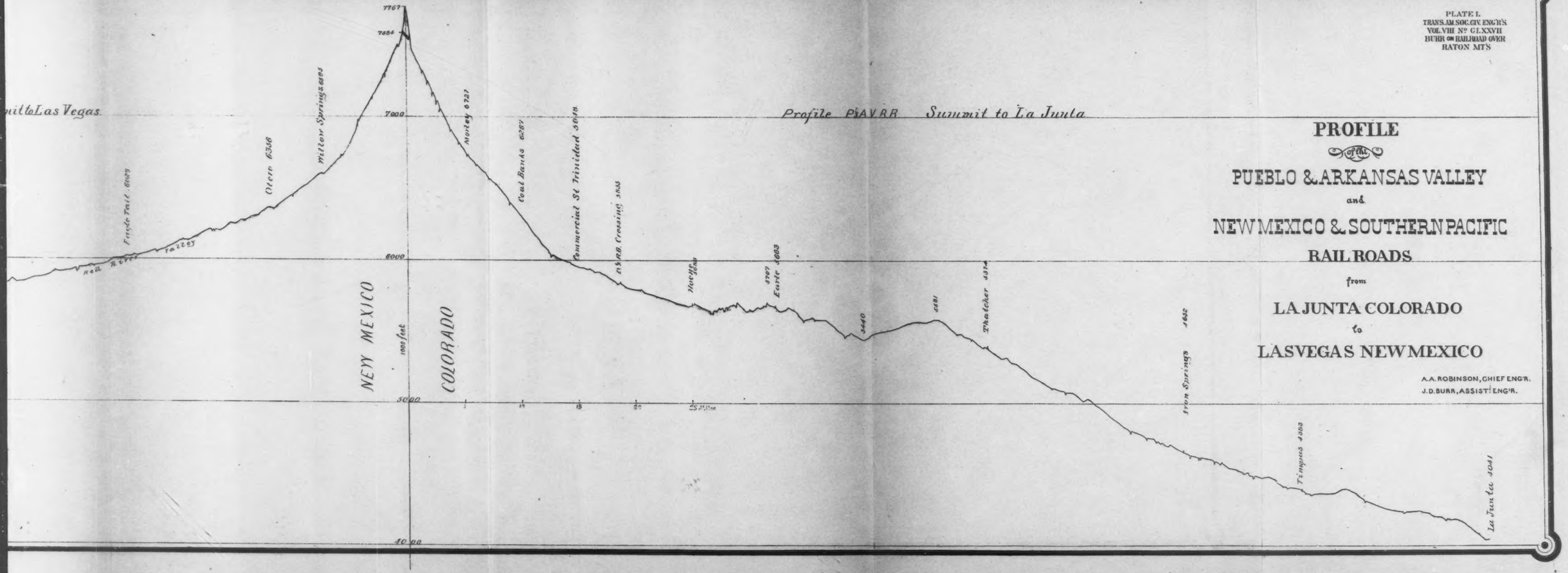
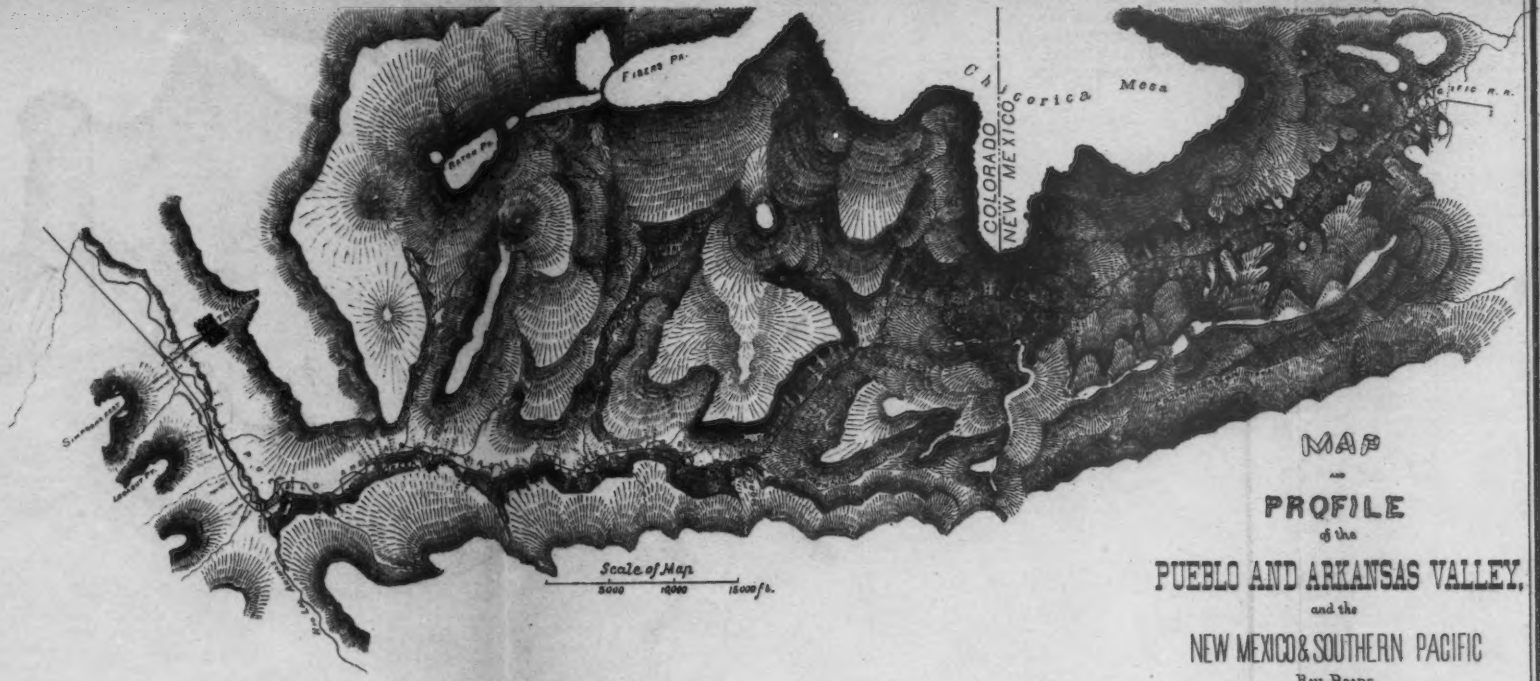


PLATE LI
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII Nº CLXXVII
BURR ON RAILROAD OVER
RATON MTS



MAP
and
PROFILE
of the
PUEBLO AND ARKANSAS VALLEY,
and the
NEW MEXICO & SOUTHERN PACIFIC
RAIL ROADS
from
TRINIDAD, COL.
To
WILLOW SPRINGS, N.M.

A. A. Robinson, Chief Engr.
J. D. Burr, Asst. Engr.

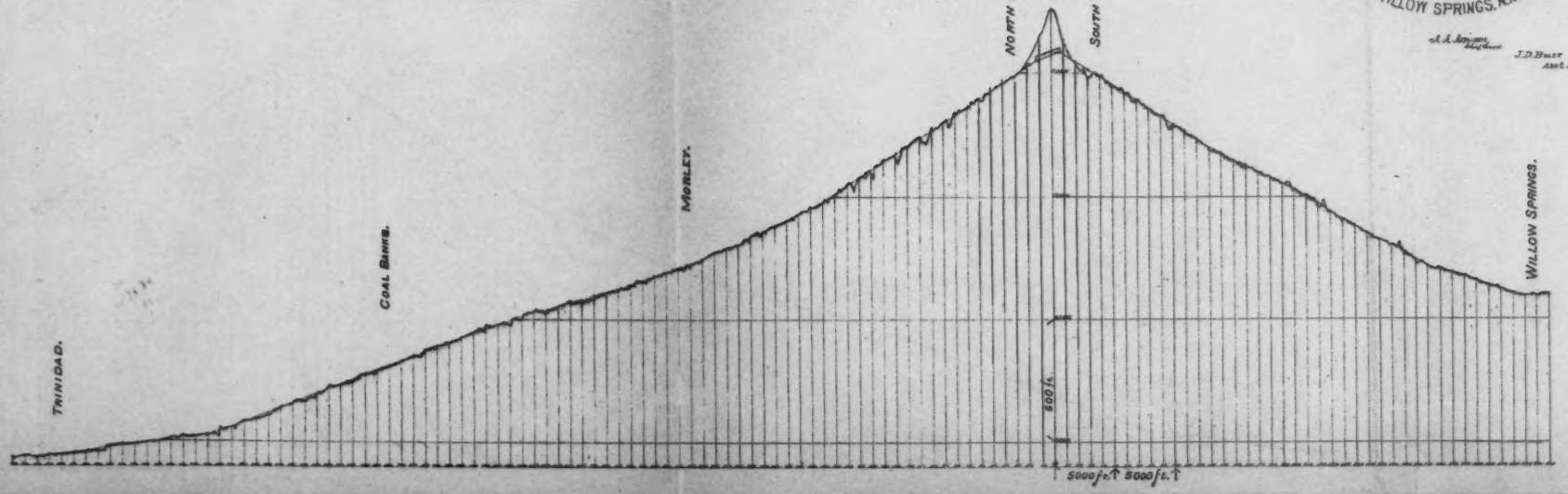


PLATE LII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII Nº CLXXXVII
BURR on RAILROAD OVER
RATON MT'S

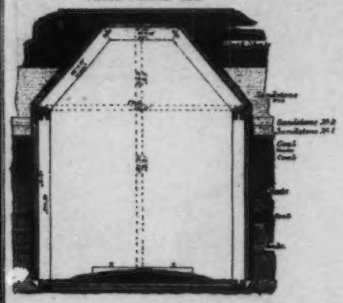
Map & Profile of the MAIN LINE & SWITCHBACK of the RATON MOUNTAINS.

N.M. & S.P.R.R.

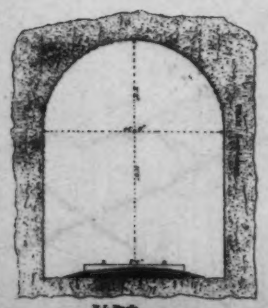
Horizontal Scale

Vertical Scale = ½ Horizontal

NORTH PORTAL SEC.



SOUTH PORTAL SEC.



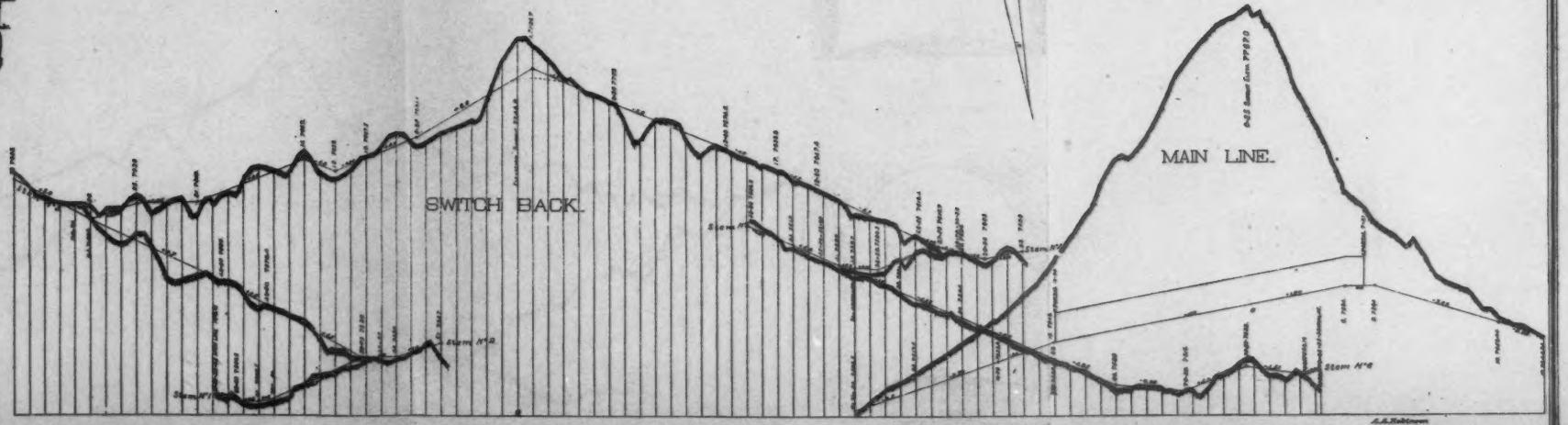
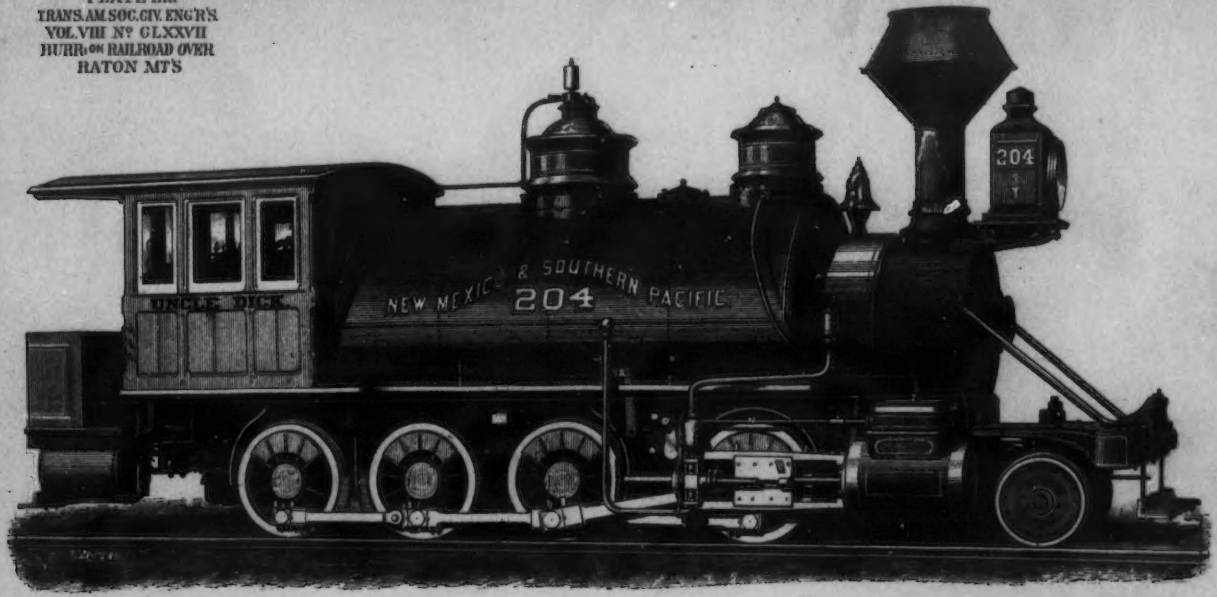



PLATE LIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. VIII Nº CLXXVII
BURR ON RAILROAD OVER
RATON MT'S